HIGH-WAYS AND DRY-WAYS; OR, THE BRITANNIA AND CONWAY TUBULAR...

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HIGH-WAYS & DRY-WAYS;

OR, THE

BRITANNIA AND CONWAY TUBULAR BRIDGES.

BY THE AUTHOR OF

'STOKERS AND POKERS.'

LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1849.

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HIGH-WAYS AND DRY-WAYS.

CHAPTER I.

THE PRINCIPLE UPON WHICH THE BRITANNIA AND CONWAY TUBULAR BRIDGES HAVE BEEN CONSTRUCTED.

In continuation of our sketch of the practical working of the London and North-Western Railway, we now offer to our readers a short descriptive outline of the aërial passages through which it is proposed by the Directors of the Chester and Holyhead Railway, that the public shall, without cuneiform sustentation, fly across the Menai Straits.

We shall divide our subject into the following compartments:—

1. The principle upon which the Britannia Bridge is constructed.

2. The mode of its construction.

3. The floating of its tubes.

4. The manner in which they are subsequently raised.

5. Mr. Fairbairn's complaint that Mr. Robert Stephenson has deprived him 'of a considerable portion of the merit of the construction of the Conway and Britannia Bridges.'

PRINCIPLE OF THE PROPOSED PASSAGE.

In the construction of a railway from Chester to Holyhead, the great difficulty which its projectors had to contend with was to discover by what means, if any, long trains of passengers and of goods could, at undiminished speed, be safely transported across that great tidal chasm which separates Carnarvon from the island of Anglesey. To solve this important problem the Company's engineer was directed most carefully to reconnoitre the spot; and as the picture of a man struggling with adversity has always been deemed worthy of a moment's attention, we will endeavour to sketch a rough outline of the difficulties which one after another must have attracted Mr. Robert Stephenson's attention, as on the Anglesey side of the Menai Straits he stood in mute contemplation of the picturesque but powerful adversaries he was required to encounter.

Immediately in his front, and gradually rising towards the clouds above him, were the lofty snow-capped mountains of Snowdon, along the sides of which, or through which, the future railroad, sometimes in bright sunshine and sometimes in utter darkness, was either to meander or to burrow.

Beneath him were the deep Menai Straits, in length above 12 miles, through which, imprisoned between precipitous shores, the waters of the Irish Sea and of St. George's Channel are not only everlastingly vibrating backwards and forwards, but at the same time, and from the same causes, are progressively rising or falling from 20 to 25 feet with each successive tide, which, varying its period of high water every day, forms altogether an endless succession of aqueous changes.

The point of the Straits which it was desired to cross—although broader than that about a mile distant, preoccupied by Mr. Telford's Suspension-bridge—was of course one of the narrowest that could be selected; in consequence of which the ebbing and flowing torrent rushes through it with such violence that, except where there is back-water, it is often impossible for a small boat to pull against it; besides which, the gusts of wind which come over the tops, down the ravines, and round the sides of the neighbouring mountains, are so sudden, and occasionally so violent, that it is as dangerous to sail as it is difficult to row; in short, the wind and the water, sometimes playfully, and sometimes angrily, seem to vie with each other—like some of Shakspeare's fairies—in exhibiting before the stranger the utmost variety of fantastic changes which it is in the power of each to assume.

But in addition to the petty annoyances which air, earth, and water could either separately or conjointly create, the main difficulty which Mr. Stephenson had to encounter was from a new but irresistible element in Nature, an 'orbis veteribus incognitus,' termed in modern philosophy *The First Lord*, or, generically, *The Admiralty.*

The principal stipulation which the requirements of War, and the interests of Commerce, very reasonably imposed upon Science was, that the proposed passage across the Menai Straits should be constructed a good hundred feet above high-water level, to enable large vessels to sail beneath it; and as a codicil to this will it was moreover required that, in the construction of the said passage, neither scaffolding nor centering should be used—as they, it was explained, would obstruct the navigation of the Straits.

Although the latter stipulation, namely that of constructing a large superstructure without foundation, was generally considered by engineers as amounting almost to a prohibition, Mr. Stephenson, after much writhing of mind, extricated himself from the difficulty by the design of a most magnificent bridge of two cast-iron arches, each of which commencing, or, as it is termed, springing, 50 feet above the water, was to be 450 feet broad and 100 feet high—the necessity for centering being very ingeniously dispensed with by connecting together the half arches on each side of the centre pier, so as to cause them to counterbalance each other like two boys quietly seated on the opposite ends of a plank supported only in the middle. This project, however, which on very competent authority has been termed 'one of the most beautiful structures ever invented,' the Admiralty rejected, because the stipulated height of 100 feet would only be attained under the *crown* of the arch, instead of extending across the *whole* of the watercourse. It was also contended that such vast cast-iron arches would take the wind out of vessels' sails, and, as a further objecticn, that they would inevitably be much affected by alternations of temperature.

Although this stern and unanticipated demand, that the passage *throughout its whole length* should be of the specified height, appeared to render success almost hopeless, it was evidently useless to oppose it. The man of science had neither the power nor the will to contend against men of war, and accordingly Mr. Stephenson felt that his best, and indeed only, course was—like poor little Oliver Twist when brought before his parish guardians—'TO BOW TO THE BOARD;' and we beg leave to bow to it too, for, gnarled as were its requirements, and flat as were its refusals, it succeeded, at a cost to the Company to which we will subsequently refer, in effecting two great objects;—first, the maintenance for ever, for the purposes of War and Commerce, of an uninterrupted passage for vessels of all nations sailing through the Menai Straits; and secondly, the forcing an eminent engineer to seek until he found that which was required; in fact, just as a collision between a rough flint and a piece of highly-tempered steel elicits from the latter a spark which could not otherwise have appeared, so did the rugged stipulations of the Admiralty elicit from Science a most brilliant discovery, which possibly, and indeed probably, would never otherwise have come to light.

But to return to the Anglesey shore of the Menai Straits.

When Mr. Stephenson, after many weary hours of rumination in his London study, beheld vividly portrayed before him the physical difficulties with which he had to contend in the breadth and rapidity of the stream; when he estimated not only the ordinary violence of a gale of wind, but the paroxysms or squalls which in the chasm before him, occasionally,—like the Erle King terrifying the 'poor baby,'—convulsed even the tempest in its career; and lastly, when he reflected that, in constructing a passage so high above the water, he was to be allowed neither centerings, scaffoldings, nor arches, it occurred to him, almost as intuitively as a man when his house is on fire at once avails himself of the means left him for escape, that the only way in which he could effect his object was by constructing in some way or other, at the height required, a straight passage, which, on the principle of a common beam, would be firm enough to allow railway trains to pass and repass without oscillation, danger, or even the shadow of risk; and it of course followed that an aërial road of this description should be composed of the strongest and lightest material; that its form should be that best suited for averting the wind; and lastly, that no expense should be spared to protect the public from the awful catastrophe that would result from the rupture of this 'baseless fabric' during the passage over it of a train.

It need hardly be stated that, whatever might be the result of Mr. Stephenson's abstract calculations on these points, his practical decision was one that necessarily involved the most painful responsibility; which indeed, if possible, was increased by the reflection that the Directors of the Chester and Holyhead Railway placed such implicit confidence in his judgment and caution, that they were prepared to adopt almost whatever expedient he might, on mature consideration, recommend.

In war, the mangled corpse of the projector of an enterprise is usually considered a sufficient atonement for his want of success; indeed, the leader of the forlorn-hope, who dies in the breach, is not only honourably recollected by his survivors, but by a glorious resurrection occasionally lives in the History of his country: but when a man of science fails in an important undertaking involving the capital of his employers and the lives of the public, in losing his reputation he loses that which *never can be revived!*

Unawed, however, by these reflections, Mr. Stephenson after mature calculations—in which his practical experience of iron-ship building must have greatly assisted him—confidently announced, first to his employers and afterwards to a Committee of the House of Commons, by whom he was rigidly examined, that he had devised the means of accomplishing that which was required; and further, that he was ready to execute his design.

The great difficulty had been in the conception and gestation of his project; and thus his severest mental labour was over before the work was commenced, and while the stream, as it hurried through the Menai Straits, as yet saw not on its banks a single workman.

The outline or principle of his invention was, that the required transit of passengers and goods across the Conway and Menai Straits should be effected through low, long, hollow, straight tubes—one for up-trains, the other for down ones—composed of wrought-iron 'boiler-plates,' firmly riveted together. He conceived that, in order to turn aside the force of the wind, these tubes ought, like common water-pipes, to be made oval or elliptical, and that they should be constructed at their final elevation on temporary platforms, upheld by chains which—notwithstanding the evident objection, in theory as well as in practice, to an admixture of moveable and immoveable parts—might of course subsequently be allowed to give to the bridge an auxiliary support, although Mr. Stephenson's experience enabled him to declare to the Committee of the House of Commons very positively that no such extra assistance would be required. He proposed that the extremities of the tubes should rest on stout abutments of masonry, terminating the large embankment by which from either side of the country each was to be approached; the intermediate portions of the aërial passage reposing at the requisite elevation upon three massive and lofty towers. Of these one was to be constructed at high-water mark on each side of the Straits. The third, no less than 221 feet in height, was to be erected as nearly as possible in the middle of the stream, on a tiny rock, which, covered with 10 feet of water at high tide, although at low water it protruded above the surface, had long been considered as a grievance by boatmen and travellers incompetent to foresee the important service it was destined to perform.

The four lengths of each of the twin tubes, when supported as described, were to be as follows:—

	Feet.
From Carnarvon embankment, terminating in its abutment, to the tower at high-water mark	274
From the latter tower to Britannia tower, situated upon Britannia rock in the middle of the stream	472
From Britannia tower to that at high-water mark on the Anglesey shore	472
From the Anglesey tower to the abutment terminating the embankment which approaches it	274
Total length of each tube	1492
Total length of both tubes	2984

Notwithstanding the bare proposal of this magnificent conception was unanswerable evidence of the confidence which the projector himself entertained of its principles, yet, in justice to his profession, to his employers, to the public, as well as to himself, Mr. Stephenson deemed it proper to recommend that, during the construction of the towers and other necessary preparations, a series of searching experiments should be made by the most competent persons that could be selected, in order to ascertain the precise shape and thickness of the immense wrought-iron aërial galleries that were to be constructed, as also the exact amount of weight they would practically bear. In short, the object of the proposed experiments was to ensure that neither more nor less materials should be used than were absolutely requisite, it being evident that every pound of unnecessary weight that could be abstracted would, *pro tanto*, add to the strength and security of the structure.

Although it was foreseen, and very candidly foretold, that these experiments would be exceedingly expensive, the Directors of the Company readily acceded to the requisition, and accordingly, without loss of time, the proposed investigation was, at Mr. Stephenson's recommendation, solely confided to Mr. William Fairbairn, a shipbuilder and boiler-maker, who was justly supposed to possess more practical experience of the power and strength of iron than any other person that could have been selected. Mr. Fairbairn, however, after having conducted several very important investigations, deemed it necessary to apply to Mr. Stephenson for permission 'to call in the aid and assistance of Mr. Hodgkinson,' a powerful mathematician, now professor in the University of London, and whom Mr. Stephenson, in his report to the Directors, dated Feb. 9, 1846, declared to be 'distinguished as the first scientific authority on the strength of iron beams.' To these two competent authorities Mr. Stephenson subsequently added one of his own confidential assistants, Mr. Edwin Clark, a practical engineer of the highest mathematical attainments, who regularly recorded and reported to Mr. Stephenson the result of every experiment,—to whom the construction and lifting of the Britannia galleries were eventually solely intrusted,—and by whom an elaborate description of that work has just been published.*

The practicability of Mr. Stephenson's hollow-beam project having thus, at his own suggestion, been subjected to a just and rigid investigation, we shall have the pleasure of briefly detailing a few of the most interesting and unexpected results; previous, however, to doing so, we will endeavour to offer to those of our readers who may not be conversant with the subject a short practical explanation of the simple principle upon which a beam, whether of wood or iron, is enabled to support the weight inflicted upon it.

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* 'With the sanction and under the immediate supervision of Robert Stephenson, Civil Engineer. A Description of the Britannia and Conway Tubular Bridges; including an Historical Account of the Design and Erection, and Details of the Preliminary Experiments, with the Theories deduced from them. Also, General Inquiries on Beams, and on the Application of Riveted Wrought-Iron Plates to Purposes of Construction; with Practical Rules and Deductions, illustrated by Experiments. By Edwin Clark, Assistant Engineer. With Diagrams and a folio volume of Plates and Drawings, illustrative of the Progress of the Works. London: Published for the Author, by John Weale, 59, High Holborn, 1849.'

If human beings can but attain what they desire, they seldom alloy the gratification they receive by reflecting—even for a moment—on the sufferings which their fellow-creatures may have undergone in procuring for them the luxury in question. Dives sometimes extols his coals, his wine, his food, his raiment, his house, his carriages, and his horses, and yet how seldom does he either allude to or ruminate on the hardships and misery which, for his enjoyment, have been endured in coal-pits, lead-mines, sugar-plantations, cotton-fields, manufactories, smelting-houses, in horticultural and agricultural labour, by the sons and daughters of Lazarus!—and if this heartless apathy characterises human beings with reference to each other, it may naturally enough be expected that, provided *inanimate* objects answer our purpose, we think not of them at all. For instance, if a beam without bending or cracking bears—as it usually does—the weight which the builder has imposed upon it, who cares how it suffers or where it suffers?

For want, therefore, of a few moments' reflection on this subject, most people, in looking up at a common ceiling-girder, consider that the corresponding upper and lower parts thereof must at all events, *pari passu*, suffer equally; whereas these upper and lower strata suffer from causes as diametrically opposite to each other as the climates of the pole and of the equator of the earth; that is to say, the top of the beam throughout its whole length suffers from severe compression, the bottom from severe extension, and thus, while the particles of the one are violently jammed together, the particles of the other are on the point of separation; in short, the difference between the two is precisely that which exists between the opposite punishments of vertically crushing a man to death under a heavy weight, and of horizontally tearing him to pieces by horses!

Now this theory, confused as it may appear in words, can at once be simply and most beautifully illustrated by a common small straight stick freshly cut from a living shrub.

In its natural form, the bark or rind around the stick is equally smooth or quiescent throughout; whereas, if the little bough firmly held in each hand be bent downwards, so as to form a bow, or, in other words, to represent a beam under heavy pressure, two opposite results will instantly appear; namely, the rind in the centre of the upper half of the stick will, like a smile puckering an old man's face, be crumpled up; while on the opposite side immediately beneath, it will, like the unwrinkled cheeks of Boreas, be severely distended—thus denoting or rather demonstrating what we have stated, namely, that beneath the rind the wood of the upper part of the stick is severely compressed, while that underneath it is as violently stretched;—indeed if the little experiment be continued by bending the bow till it breaks, the splinters of the upper fracture will be seen to interlace or cross each other, while those beneath will be divorced by a chasm.

But it is evident on reflection that these opposite results of compression and extension must, as they approach each other, respectively diminish in degree, until in the middle of the beam, termed by mathematicians 'its neutral axis,' the two antagonist forces, like the anger of the Kilkenny cats, or, rather, like still-water between tide and back-stream, become neutralised, and, the laminæ of the beam consequently offering no resistance either to the one power or to the other, they are literally useless.

As therefore it appears that the main strength of a beam consists in its power to resist compression and extension, and that the middle is comparatively useless, it follows that in order to obtain the greatest possible amount of strength, the given quantity of material to be used should be accumulated at the top and bottom where the strain is the greatest—or in plain terms the middle of the beam, whether of wood or iron, should be bored out. All iron girders, all beams in houses, in fact all things in domestic or naval architecture that bear weight, are subject to the same law.

The reader has now before him the simple philosophical principle upon which Mr. Stephenson, when he found that he was to be allowed neither scaffolding, centering, nor arches, determined to undertake to convey at undiminished speed the Chester and Holyhead Railway's passenger and goods traffic across the Conway and Menai Straits through hollow tubes instead of attempting to do so upon solid beams; and as a striking and perhaps a startling exemplification of the truth of his theory, it may be stated that although his plate-iron galleries, suspended by the tension as well as supported by the compression of their materials, have on mature calculations been constructed to bear nearly nine times the amount of the longest railway train that could possibly pass through them (namely, one of their own length), yet if, instead of being hollow, they had been a *solid* iron beam of the same dimensions, they would not only have been unable to sustain the load required, but would actually have been bent by —or, metaphorically, would have fainted under—their own weight!

EXPERIMENTS.

One of the most interesting and important results of the preliminary investigations so ably conducted by Mr. Fairbairn and his friend and associate Mr. Hodgkinson, was the astonishing difference found to exist between the power of cast and that of wrought iron to resist compression and extension. From the experience which engineers and builders had obtained in imposing weights upon cast-iron girders of all shapes and sizes, it had long been considered almost a mechanical axiom that iron possessed greater power to resist compression than extension; whereas Mr. Fairbairn's experiments, to his surprise as well as to that of all who witnessed them, most clearly demonstrated that, after bearing a certain amount of weight, the resisting properties of cast and of wrought iron are diametrically opposite; in short, the results in figures proved to be nearly as follows:

Cast-iron can resist per square inch—

Compression of from 35 to 49 tons.
Extension of ,, 3 7

Wrought-iron can resist per square inch—

Compression of from 12 to 13 tons.
Extension of ,, 16 18

The unexpected results thus obtained were of incalculable practical value; for, if the preliminary experiments proposed by Mr. Stephenson had not been made, he, Mr. Fairbairn, Mr. Hodgkinson, Mr. Clark, and indeed all the eminent engineers and mathematicians of the present day, would—on the correct principle of everywhere adjusting the thickness of iron to the force it has to resist—have erroneously concurred in recommending that the proposed *wrought*-iron tubes for crossing the Conway and Menai

Straits should be constructed stronger at bottom than at top, instead of, as it appears they ought to be, stronger at top than at bottom—in consequence of which error the aërial gallery would have been improperly weakened in one part by an amount of iron which would have unscientifically overloaded it at another, and thus, like Falstaff's 'increasing belly and decreasing legs,' the huge mass, with diminished strength, would have laboured under unnecessary weight.

By continuing with great patience and ability the experiments above referred to, it was finally ascertained that the relative strength of *wrought* iron in the top and bottom of the tubes should be in the proportion of about 5 to 4; and whereas, had they been constructed of *cast* iron, these proportions would have been reversed in the higher proportion of nearly 5 to 1, it may reasonably be asked why, if the latter material bears compression so much better than the former, it was not selected for the *top* of the tube? In theory this adjustment of the two metals to the force which each was peculiarly competent to resist, would have been perfectly correct. It, however, could not practically be effected, from the difficulty of casting as well as of connecting together plates 10 and 12 feet in length of the very slight thicknesses required. Mr. Stephenson, therefore, adhered to his original determination to make the whole of his aërial galleries of wrought-iron; and we may here observe that, to ensure the public from accident, he further resolved that the amount of the force of extension upon them should be limited to only one-third of their power of resistance, that of compression to one-half—the reason of the difference being that, inasmuch as any little flaw in the iron would infinitely more impair its power to resist extension than compression, it was evidently safer to approximate the limits of the latter than of the former.

As the exact strength of a hollow wrought-iron tube such as was proposed was unknown to engineers, it was deemed necessary by Mr. Stephenson that its *form* as well as the disposition of its materials should be correctly ascertained. This portion of the investigation Mr. Fairbairn and his colleagues with great care and ability conducted by subjecting tubes of different shapes to a series of experiments, the results of which were briefly as follows:—

1. CYLINDRICAL TUBES, on being subjected to nine very severe trials, failed successively by collapsing at the top—or, in other words, by evincing inability to resist compression:—the tube, losing its shape, gradually became elongated or lantern-jawed, while the two extremities were observed to flatten or bulge out sideways—besides which the ends, which for precaution sake rested on concentric wooden beds, invariably bent inwards.

2. ELLIPTICAL TUBES, with thick plates riveted to the top and bottom, had been particularly recommended for experiment by Mr. Stephenson. These tubes under heavy pressure displayed greater stiffness and strength than round or cylindrical ones; nevertheless, after being subjected to a variety of torturing experiments of a most ingenious description, they all evinced comparative weakness in the top to resist compression. They likewise exhibited considerable distortions of form.

3. A family weakness in the head having been thus detected in all models circular at bottom and top, RECTANGULAR TUBES were in their turn next subjected to trial, and as they at once appeared to indicate greater strength than either of the other two forms had done, a very elaborate and interesting investigation was pursued by

Mr. Fairbairn, who, by the light of his experiments, soon satisfied himself of the superiority of this form over the other two; and as every successive test confirmed the fact, he continued his search with an energy that has only since been equalled by the American judge who, on arriving at California, deserted the bench for 'the diggings.'

The following is an abstract of the important result of about forty experiments made by Messrs. Fairbairn, Hodgkinson, and Clark, on the comparative strength of circular, elliptical, and rectangular tubes:—

CIRCULAR, 13; ELLIPTICAL, 15; RECTANGULAR, 21.

As soon as the rectangular was by the investigation recommended by Mr. Stephenson clearly ascertained to be the best form of hollow tube that could be selected, the next important problem to be determined by experiment was what amount of strength should be given to it, or, in other words, what should be the thickness of its top and bottom, in which, as we have shown, consisted its main power.

The investigations on this subject soon demonstrated that if, instead of obtaining this thickness by riveting together two or three layers of plates, they were, on the principle of the beam itself, placed in horizontal strata a foot or two asunder—the included hollow space being subdivided by small vertical plates into rectangular passages or flues extending along the whole top as well as bottom of the tube—an immense addition of strength, with very nearly the same weight of material, would be obtained, and this adaptation proving highly advantageous, it was deemed advisable by Mr. Stephenson that further experiments should be made by Mr. Fairbairn and his colleagues to determine finally the precise form and proportions of the great tubes.

For this object an entirely new model tube, one-sixth of the dimensions of the intended Britannia Bridge, was very carefully constructed; and the cellular tops and bottoms thereof, as well as the sides, were subjected to a series of experiments until the exact equilibrium of resistance to compression and extension, as also the variations in the thicknesses of the plates in the several parts of the tube as they approached or receded from different points of support, were most accurately ascertained.

In these as well as in all the previous experiments the trial tubes were loaded till they gave way—the results being accurately recorded and transmitted by Mr. E. Clark to Mr. Stephenson, who in return confidentially assisted Mr. C. with his opinion and advice. From the fibrous nature of wrought iron, as compared with the crystalline composition of the cast metal, the tendency to rupture in most of these experiments was slow and progressive. Destruction was never instantaneous, as in cast iron, but it advanced gradually; the material, for some time before absolute rupture took place, emitting an unmistakeable warning noise; just as a camel, while kneeling on the burning sandy desert, and while writhing his head from one side to the other, snarls, grunts, grumbles, and groans louder and louder, as his swarthy turbanheaded owners keep relentlessly adding package after package to his load.

Although it can mathematically be shown that the two sides of a thin hollow tube are of but little use except to keep the tops and bottoms at their duty—the power of resistance of the latter being, however, enormously increased by the distance that separates them—it was nevertheless necessary to ascertain the precise amount of lateral strength requisite to prevent the aërial gallery writhing from storms of wind. The riveting process was likewise subjected to severe trial, as also the best form and application of the slender ribs termed 'angle-irons,' by which not only the plates were to be firmly connected, but the tube itself materially strengthened;—in fact, the angle-irons were to be its bones, the thin plate-iron covering being merely its skin.

Mr. Stephenson had two main objects in instituting the investigations we have detailed. First, to determine by actual experiment what amount of strength *could* be given to his proposed galleries; and, secondly, of that maximum *how much* it would be proper for him to exert. And as his decisions on these subjects will probably be interesting to our readers, most especially to that portion of them whose fortunes or fate may doom them occasionally to fly through his baseless fabric, we will endeavour very briefly to explain the calculations on which they appear to have been based.

As a common railway train weighs upon an average less than a ton per foot,—as the greatest distances between the towers of the Britannia Bridge amount each to 460 feet,—and as it is a well-known mathematical axiom among builders and engineers that any description of weight spread equally along a beam produces the same strain upon it as would be caused by half the said weight imposed on *the centre*,—it follows that the maximum weight which a monster train of 460 feet (an ordinary train averages about half that length) could at one time inflict on any portion of the unsupported tube would amount to 460 tons over the whole surface, or to 230 tons at the centre.

Now, to ensure security to the public, Mr. Stephenson, after much deliberation, determined that the size and adjustment of the iron to be used should, according to the experiments made and recorded, be such as to enable the aforesaid unsupported portions of the tube (each 460 feet in length) to bear no less than 4000 tons over its whole surface, or 2000 tons in the centre, being nine times greater than the amount of strength necessarily required; and as the results—expected as well as unexpected—of the searching investigation which had been instituted, incontestably proved that this Herculean strength could be imparted to the galleries without the aid of the chains, which, even as an auxiliary, had been declared unnecessary,—and as Mr. E. Clark had very cleverly ascertained that it would be cheaper to construct the tubes on the ground than on the aërial platform as first proposed,—Mr. Stephenson determined, on mature reflection, to take upon himself the responsibility of reporting to the Directors of the Chester and Holyhead Railway that this extra catenary support, which would have cost the Company 150,000*l.*, was wholly unnecessary. Indeed, such was the superabundance of power at his command, that, without adding to the weight of the rectangular galleries, he could materially have strengthened them by using at their top and bottom circular flues instead of square ones, which, merely for the convenience of cleaning, &c., were adopted, although the former were found on experiment to bear about 18 tons to the square inch before they became crushed, whereas the latter could only support from 12 to 14 tons.

But the security which Mr. Stephenson deemed it necessary to ensure for the public may further be illustrated by the following very extraordinary fact:—It has been mathematically demonstrated by Messrs. Hodgkinson and Clark, as well as practically proved by Mr. Fairbairn—indeed it will be evident to any one who will go through the necessary calculations on the subject —that the strain which would be inflicted on the iron-work of the longest of Mr. Stephenson's aërial galleries by a monster train sufficient to cover it from end to end, would amount to six tons per square inch:—which is exactly equal to the constant stress upon the chains of Telford's magnificent suspension Menai Bridge when, basking in sunshine or veiled in utter darkness, it has nothing to support but its own apparently slender weight!

LATERAL STRENGTH.—The aërial galleries having, as above described, been planned strong enough for the safe conveyance of goods and passengers at railway speed, it became necessary to calculate what *lateral* strength they would require to enable them to withstand the storms, tempests, squalls, and sudden gusts of wind to which from their lofty position they must inevitably be exposed.

The utmost pressure of the hurricane, as estimated by Smeaton—but which is practically considered to be much exaggerated—amounts to about 46 lbs. to the square foot; and this, on one of the large tubes (460 feet long by an average of rather less than 30 feet high) would give a lateral pressure of 277 tons over the whole surface, or of 133 tons on the centre.

To determine the competency of the model tube to resist proportionate pressure to this amount, it was turned over on its side; and, having by repeated experiments been loaded and overloaded until it was crushed, the result fully demonstrated to Mr. Stephenson's satisfaction its power to resist, according to his desire, a lateral pressure more than five times greater than that which it is in the power of the hurricane to inflict.

The experimental information required by Mr. Stephenson having, by the zeal and ability of Mr. Fairbairn, Mr. Hodgkinson, and Mr. Clark, been finally obtained, the next points for consideration came to be, where these gigantic twin-tubular galleries should be constructed, and, when constructed, by what power, earthly or unearthly—it will appear that the latter was found necessary —they should be raised to the lofty position they were decreed to occupy.

After much reflection on Mr. E. Clark's valuable suggestions on these subjects, Mr. Stephenson determined —1st. That the four shortest galleries, each 230 feet in length, (to be suspended at the height in some places of 100 feet between the two land towers and the abutments of the approaching embankments,) should, as he had originally proposed, be at once permanently constructed on scaffoldings in the positions in which they were respectively to remain;

2ndly. That the four longest galleries (each 472 feet in length), which were eventually to overhang the straits, should be completely constructed at high-water mark on the Carnarvon shore, upon wooden platforms about 400 feet westward of the towers on which they were eventually to be placed;

3rdly. That to the bases of these towers they should, when finished, be floated on pontoons, from which they were to be deposited on abutments in the masonry purposely made to receive them; and,

4thly. That the tubes should be raised to and finally deposited in their exalted stations by the slow but irresistible power of hydraulic presses of extraordinary force and size.

CHAPTER II.

CONSTRUCTION OF THE TUBES AND TOWERS.

The locality selected for the formation of the tubes having been cleared, a substantial platform, composed of balks of timber covered with planks, was very quickly laid down.

In the rear of this immense wooden stage, which extended along the shore no less than half a mile, covering about three acres and a half, there were erected three large workshops, containing forges and machinery of various descriptions, for belabouring, punching, and cutting plate-iron. There were likewise constructed five wharves with cranes for landing materials, as also six steam-engines for constant work. The number of men to be employed was—

On iron-work about . . .	700
At stone-work for the towers .	800
Total . . .	1500

With mushroom growth temporary shanties or wooden cottages, whitewashed on the outside, suddenly appeared in the green fields and woods immediately adjoining; besides which, accommodation was provided for a schoolroom, schoolmaster, clergyman, and in case of accidents, for a medical man, the whole being agreeably mixed up with a proportion of wives, sweethearts, and children, sufficient for cooking, washing, sewing, squalling, &c. Nevertheless, notwithstanding these alluring domestic arrangements, many sturdy independent workmen preferred sleeping in villages four and five miles off, to and from which they walked every morning and evening, in addition to their daily work; the remainder gipsying in the encampment in various ways, of which the following is a sample:—

An Irish labourer, known only by the name of 'Jemmy,' *bought* for himself a small clinker-built room. As 'lodgings,' however, soon rose in price, and as he had not time to keep a pig, he resolved to be satisfied henceforwards with half his tiny den, and accordingly let the remainder to a much stronger fellow-countryman, who, being still less particular, instantly let half of his half to a very broad-shouldered relation, until, like other Irish landlords we could name, poor 'Jemmy' found it not only very difficult to collect, but dangerous even modestly to *ask* for, 'his rint'! and thus in a short time, in consequence of similar 'pressure from without,' almost every chamber was made to contain four beds, in each of which slept two labourers.

As soon as the preliminary wharves, platforms, shanties, and workshops were completed, there instantly commenced a busy scene strangely contrasted with the silence, tranquillity, and peaceful solitude that had previously characterised the spot. While large gangs of masons were excavating the rocky foundations of the land towers, sometimes working in dense groups, and sometimes, in 'double quick time,' radiating from each other, or rather from a small piece of lighted slow-match, sparkling in the jumper-hole of the rock they had been surrounding;—while carts, horses, and labourers in great numbers were as busily employed in aggregating the great embankments by which these towers were to be approached;—while shiploads of iron from Liverpool—of Anglesey marble from Penmon—of red sandstone from Runcorn in Cheshire—at rates dependent upon winds and tides, were from both entrances to the straits approaching or endeavouring to approach the new wharves;—while almost a forest of scaffold balks of the largest and longest description—like Birnam wood coming to Dunsinane—were silently gliding towards the spot;—while waggons, carts, post-chaises, gigs, horses, ponies, and pedestrians, some of the latter carrying carpet-bags and some bundles, &c., were to be seen on both sides of the straits eagerly converging across the country to the new settlement or diverging from it:—the unremitting clank of hammers,—the moaning hum of busy machinery,—the sudden explosion of gunpowder—the white vapour from the steam-engines,—and the dark smoke slowly meandering upwards from their chimneys, gave altogether interest, animation, and colouring to the picture.

As our readers will, however, probably be anxious to know how the great tubes which have been delineated are practically constructed, we will shortly describe the operation, which, we are happy to say, is contained in a vocabulary of only three words, these aërial galleries being solely composed of—Plates,—Rivets,—and Angle-Irons.

PLATES.

The wrought-iron plates which form the top, bottom, and sides of the Britannia 'land tubes,' 230 feet in length, are, of course, slighter than those required for the four, each 460 feet, which overhang the stream.

For these long tubes—which are of the same height and breadth as the shorter ones—the dimensions of the plates are as follows:—

For the bottom	12 feet in length, 2 feet 4 inches to 2 feet 8 inches in breadth, $\frac{7}{16}$ to $\frac{9}{16}$ inch in thickness.
For the top	6 feet in length, 1 foot 9 inches to 2 feet $1\frac{1}{2}$ inch in breadth, $\frac{5}{8}$ to $\frac{3}{4}$ inch in thickness.
For the sides	6 feet to 6 feet 6 inches in length, 2 feet in breadth, $\frac{1}{2}$ to $\frac{3}{4}$ inch in thickness.

Although these plates have been severally forged with every possible attention, yet, to render them perfectly flat, they are not allowed by Mr. Stephenson to be used for the tubes until each has been passed by the Company's superintendent between two uncompromising massive iron rollers, worked by steam, which, by revolving, quietly remove or rather squeeze down that variety of pimples, boils, lumps, bumps, and humps which from unequal contraction in the process of cooling occasionally disfigure the surface of plate-iron, and which in the workman's dictionary bear the generic name of '*buckles.*' When the plates, the largest of which weigh about 7 cwt., have been thus accurately flattened, they are, one after another, according to their dimensions, carried by two or more men towards one of several immense wrought-iron levers, which, under the influence of steam, but apparently of their own accord, are to be seen from morning till night, whether surrounded by workmen or not, very slowly and very indolently ascending and descending once in every three seconds.

Beneath the short end of this powerful lever there is affixed to the bottom of a huge mass of solid iron a steel bolt—about the length, thickness, and latent power of Lord John Russell's thumb—which, endowed with the enormous pressure of from 60 to 80 tons, sinks, at every pulsation of the engine, into a hole rather larger than itself, perforated in a small anvil beneath.

As soon as the labourers of the Department bearing each plate arrive at this powerful machine, the engineer in charge of it, assisted by the carrying-men, dexterously places the edge of the iron upon the anvil in such a position that the little punch in its descent shall consecutively impinge upon one of a series of chalk dots, which, at four inches from each other and 1½ inch from the edge, have been previously marked around the four sides of the plate; and thus four rows of rivet-holes averaging an inch in diameter are, by the irresistible power we have described, pierced through plate-iron from one-half to three-fourths of an inch in thickness, quite as easily as a young cook playfully pokes her finger through the dough she is kneading, or as the child Horner perforated the crust of his Christmas pie, when

'He put in his thumb
And pulled out a plum,
And said—What a good boy am I!'

Some of the steam arms or levers just described are gifted with what may be termed 'double-thumbs,' and accordingly these perforate *two* holes at a time, or forty per minute—the round pieces of iron cut out falling, at each pulsation of the engine, upon the ground, through the matrix or perforation in the anvil.

When the plates, averaging from six to twelve feet in length by above two feet in breadth, have been thus punched all round, and before they are brought to the tube, they are framed together on the ground in compartments of about twenty plates each (five in length and four in breadth), in order to be connected to each other by what are termed *covering-plates* and *angle-irons.*

In order to prepare the former (which are half an inch in thickness, one foot in breadth, and about two feet long) they are heated in a small furnace, when, instead of passing between rollers, they are put under a stamping, or as it is technically termed a *joggling* block, which by repeated blows renders their surface perfectly flat; after which a series of holes corresponding in size as well as in distance from each other with those in the 'plates' are punched all along the outer edge of each of their four sides. When thus prepared, two of these small covering plates—one on each side—are made to cover and overlap the horizontal line of windage existing between the edges of the plates, which, as we have stated, have been previously arranged so as to touch each other; and bolts being driven through the corresponding holes of the three plates (the large plates lying between the two covering ones), they are firmly riveted together by the process we shall now describe.

RIVETS.

In the construction of the Britannia tubes there have been required no less than two millions of bolts, averaging ⅞ths of an inch in diameter and 4 inches in length. The quantity of rod-iron consumed for this purpose has therefore amounted in length to 126 miles, and in weight to about 900 tons!

The mode in which these legions of rivets have been constructed is briefly as follows:—

At the western end of the Company's principal forging establishment there stands a furnace or trough, full of pieces of rod-iron from 3¾ to 4¾ inches in length, packed together as closely as soldiers in a solid square of infantry. As soon as, by the fiery breath of bellows worked by steam, they have been made uniformly red-hot, a little boy, whom they are all obliged to obey, rapidly and without partiality, favour, or affection, picks them out one after another through the furnace-door with a pair of pincers, from which he quietly drops them perpendicularly into eight moulds, each of which being about ¾ of an inch shallower than the length of the piece of iron it respectively receives, they of course all equally protrude about that distance above the surface.

In this position they are handed over to a pale sturdy engine-man, or executioner, who, with about as much mercy as Procrustes used to evince towards those who slept on his bed, immediately places them upon an anvil, towards which there very slowly descends a huge superincumbent mass of iron pressed downwards by an immense long wrought-iron lever worked by steam.

By this despotic power, the red protruding portion of each little rod is by a single crunch inexorably flattened, or 'fraternised;' and thus suddenly converted—*nolens volens*—into a bolt, it is no sooner thrown upon the ground than the mould from which it was ejected is again, by the child in waiting, filled with another raw red-hot recruit, who by a process exactly the reverse of decapitation is shortened, not by the *loss* but by the *acquisition* of a head!

However, after all, just as 'the Marquis of —— is not the Duke of ——,' so is a bolt not a rivet, nor does it become one, until, like a bar-shot, it is made double-headed, an important process which has now to be described.

As soon as each 'set' of the half-inch iron plates which form the sides, top, and bottom of the Britannia tubes, have by a travelling crane been lifted—technically termed 'picked up'—into their places, and have been made to touch each other as closely as possible, a moveable stage on wheels is drawn close to the outside of the tube, for the purpose of firmly connecting every set of plates to that which on each side adjoins it. This work is performed by what is termed 'a set of riveters,' composed of two 'Riveters,' one 'Holder-up,' and two Rivet-boys.

As soon as the two first have ascended the scaffolding on the outside of the tube, and when the Holder-up, sitting on a board suspended by ropes from the roof, has exactly opposite to them taken up his position on the inside, one of the boys quickly abstracts from a furnace, conveniently placed for the purpose, a red-hot bolt, which by a circular swing of his pincers he hurls inside the tube towards the other boy, his comrade or playfellow, who, as actively as possible, with a similar instrument snapping it up, not only runs with it towards the Holder-up, but as long as he can reach the rivet-holes inserts it for him therein. As soon as this is effected, the Holder-up presses against it an enormous iron hammer, which forces it outwards until it is stopped by its own head. The red protruding bolt is now mercilessly assailed by the two Riveters, whose sledge-hammers meeting with a sturdy reaction from that of the Holder-up, which by a vast leverage or length of handle elastically returns blow for blow, the bolt, in about thirty seconds, becomes double-headed, when one of the Riveters, dropping his hammer, snatches up a steel mould about 9 inches long, called *a swage*, which he continues to hold upon the newly-formed head until his comrade, by repeated blows of his hammer, has *swaged* it into a workmanlike form.

The bolt is thus finally converted into a rivet, which, by contracting as it cools, binds together the plates even more firmly than they had already been almost cemented by the irresistible coercion of three sledge-hammers;

indeed they are so powerfully drawn together, that it has been estimated it would require a force of from four to six tons to each rivet to cause the plates to slide over each other.

The bolts for the upper holes of the interior (which, being about 30 feet high, are of course completely out of the Rivet-boy's reach) are dropped by him into a concentric iron ring, which, by a wire and cord passing over a pulley attached to one of the uppermost plates, is rapidly raised, until the Holder-up is enabled by pincers to grasp the fiery iron, which, on being inserted into its hole, he then instantly, as before, presses with his hammer.

By the operations above described, 'a set of riveters' usually drive per day about 230 rivets, of which in each plate there are about 18 per yard, in two rows, averaging only 2½ inches of clear space between each bolt-head. On the large tubes alone there have been employed at once as many as 40 sets of riveters, besides 26 'platers,' or men to adjust the plates, each having from three to four men to assist him; and when this well-regulated system is in full operation it forms altogether not only an extraordinary but an astounding scene.

Along the *outside* of the tube, suspended at different heights, are to be seen in various attitudes 80 Riveters—some evidently watching for the protruding red bolt, others either horizontally swinging their sledge-hammers, or holding the rivet-swage.

In the *inside* of this iron gallery, which is in comparative darkness, the round rivet-holes in the sides as well as in the roofs not only appear like innumerable stars shining in the firmament of heaven, but the light beaming through each forms another as bright a spot either on the ground or on the internal surface of the tube. Amidst these constellations are to be faintly traced, like the figures on a celestial globe, the outlines of the Holders-up, sitting at different altitudes on their respective stages. Beneath them 40 or 50 Rivet-boys are dimly seen, some horizontally hurling red-hot bolts, others with extended pincers running forwards with them, while fiery bolts, apparently of their own accord, are to be observed vertically ascending to their doom. This cyclopean dance, which is of course most appropriately set to music by the deafening reverberations of 70 or 80 sledge-hammers, is not altogether without danger; for not only does a '*holder-*UP' from a wrong movement occasionally—like a political Phaëton—all of a sudden tumble *down*, but the rivet-boys, generally unintentionally, but occasionally, it is said, from pure mischief, burn each other more or less severely, in which cases a couple of these little sucking Vulcans, utterly unable, from incessant noise, to quarrel by words, fall to blows, and have even been observed to fight a sort of infernal duel with pincers, each trying to burn his opponent anywhere and everywhere with his red-hot bolt!

But by far the most curious part of the riveting process is to be seen on the flat roof or top of the tube. This immense deck, which we have already stated to be 472 feet in length, is composed of a pavement of plates to be connected together by 18 longitudinal rows of rivets, the heads of which are to be only 2½ inches apart. Beneath this surface, at a depth of only 1 foot 9 inches, there is, to give additional strength, a similar stratum of plates, the space included between both being divided into eight compartments called flues, 21 inches deep by 20 inches broad, exactly resembling those of a common stove. After the horizontal bottoms and upright sides of these eight flues have been firmly connected together by the battering process we have just described, the upper stratum of plates are loosely laid down, and, being thus by the superincumbent weight of the iron covering securely adjusted, their final connexion is effected as follows :—

A tiny rivet-boy—we observed one little mite only ten years of age—in clothes professionally worn into holes at the knees and elbows—crawling heels foremost for a considerable distance into one of these flues as easily as a yellow ferret trots into a rabbit-hole, is slowly followed by his huge lord and master *the holder-up*, who exactly fits the flue, for the plain and excellent reason, that by Mr. Stephenson the flue was purposely predestined to be exactly big enough to fit *him;* and as, buried alive in this receptacle, he can move but very slowly, he requires some time, advancing head foremost, to reach the point at which he is to commence his work. On arriving there, his first process, lying on his left side, is with his right hand to pass through one of the rivet-holes in the plate above him a little strong hook, to which is attached a short hempen loop, or noose, which, supporting the heavy end of his huge hammer, forms a fulcrum upon which he can easily raise it against the roof, simply by throwing his right thigh and leg over the extremity of the long lever or handle of the instrument.

When similar preparations, by the injection of other little Rivet-boys and other stout Holders-up into several of the other flues, have been made, the signal for commencing operations is given by several red-hot bolts falling, apparently from the clouds, among the Riveters, who, leaning on their sledge-hammers, have been indolently awaiting their arrival. These bolts have been heated on the outside of the tube on the ground immediately beneath, in a portable furnace, from which a gang of lithesome rivet-boys in attendance extract them as fast as they are required, and then walking away with them, without looking upwards, or apparently caring the hundred-thousandth part of the shaving of a farthing where they may fall, or whom they may burn, they very dexterously, by a sudden swing of their pincers, throw them almost perpendicularly about 45 feet, or about 10 feet higher than the top of the tube, upon which, as we have stated, they fall among the assembled riveters as if they had been dropped from the moon.

As soon as these red-hot meteors descend upon the flat roof, another set of rivet-boys eagerly snap them up, and each running with his bolt, not to the spot where it is required, but to one of certain holes in the plate made on purpose for its insertion, he delivers it into the pincers of the little sweep, rivet-boy, or Ascanius, within the flue, who, having been patiently waiting there to receive it, crawls along with it towards his Pius Æneas, the stout recumbent *holder-up*. As soon as he reaches him he inserts for him the small end of the bolt into the hole for which it has been prepared, and through which, in obedience to its fate, it is no sooner seen to protrude, than the sledge-hammers of the expectant riveters, severely jerking at every blow the heavy leg of the poor holder-up, belabour it and '*swage*' it into a rivet.

The red-hot iron—unlike the riveters—cools during the operation we have just described; and even if a bystander, from being stone-blind, could not *see* the change in its temperature, it could easily be recognised by the difference in the *sound* of the hammers between striking the bolt while it is soft and hot, and when it has gradually become cool and hard. But whatever may be the variety of colours or of noises which accompany the formation of every one of these roof-rivets, it is impossible to witness the operation we have just described without acknowledging, with a deep sigh, how true is the proverb that 'one half of the world,' especially the rich half, 'does not know how the other half lives;' indeed, unless we had witnessed the operation, we could scarcely have believed that any set of human beings, or rather of fellow-creatures, could professionally work from morning till night, stuffed horizontally into a flue of such small dimensions,—that they could endure the confinement which only allows them, by changing from one side to another, to throw sometimes the right leg and sometimes the left over the elastic handle of a hammer,—and above all that they could bear the deafening noises created close to and immediately thundering into their very ears!

In attentively watching the operations just described, we observed that at the *sides* of the tube it required generally eighteen blows of the hammer to flatten the end of the bolt, and then twelve blows on the '*swage*' to finish the head of the rivet; whereas, on the *roof*, the former operation was usually effected by only twelve blows, and the latter by eight or nine. At first, we conceived that this difference might be caused by a reduction in the sizes of the plates and bolts: but those in the roof proving to be the thickest and longest, we, on a few moments' reflection, ascertained that the reduction of labour in riveting the roof is caused by the sledge-hammers descending upon it by gravity as well as by the main strength of the riveters; whereas, at the *sides*, they are worked by the latter power only.

As the operation cannot of course be carried on when the weather is either windy or wet, the riveters, holders-up, and rivet-boys very properly receive high wages. The first of these classes, however, strange to say, look *down* upon the holders-*up* as their inferiors, or rather as their menials; and again, the holders-up bully the little ragged-elbowed rivet-boys who wait upon *them;* but so it is, not only over the whole surface of the earth, but in the deep blue sea! In the stomach of the shark we find a dolphin, in whose stomach there is found a flying-fish, which, on dissection, has been found to have preyed on a smaller tribe, and so on. We have, therefore, no unkind reflections to cast upon 'riveters,' 'holders-up,' or 'rivet-boys' for frowning upon, bullying, or burning each other.

ANGLE-IRONS.—The plates of the tubes having throughout been scientifically adjusted in the different positions best suited to resist the variety of strains to which, from external or internal causes, they can possibly be subjected, are finally connected together by small ribs, which are firmly riveted to the plates. The quantity of *angle-iron* thus worked through the top, bottom, and sides of all the tubes amounts to no less than sixty-five miles! The sides are, moreover, connected to the top and bottom of each tube by small triangular plates, called *gussets*, which powerfully prevent the bridge from twisting or writhing under the lateral pressure of the wind.

CHAPTER III.

THE FLOATING OF THE TUBE.

THE GATHERING.—On the principle of 'Quæ regio in terris nostri non plena laboris?' we determined, in the family way, to join that respectable crowd of brother and sister reviewers, ill-naturedly called 'gapers and gazers,' who from all parts of the United Kingdom of Great Britain and Ireland, from the Continent of Europe, and even from the United States of America, were, in various degrees of agitation, inquisitively converging upon North Wales, for the purpose of beholding something which, although unanimously declared to be 'quite new,' few appeared very clearly to understand.

All agreed that the wonder they wished to witness was *The Britannia Bridge;* but what was its principle or its form, what it was to do, or what was to be done to it, no person appeared able to explain to anybody. Some nasally 'guessed' it was to be raised; others—*ore rotundo*—positively declared it was to be only floated. One man truly enough affirmed 'it was to go from earth to earth, straight through the air, to avoid the water'—but by which or by how many of these three elements, or by what other powers, the strange transaction was to be effected, deponent, on cross-examination, was utterly unable to detail.

As the railway from Chester—where the principal portion of the travellers had concentrated—has for several miles been constructed along the sands of the Irish Sea, the passengers during that portion of their journey had ample space and opportunity for calm observation or reflection: as soon, however, as the heavily-laden trains reached Rhyl, there was gradually administered to the admirers of the picturesque a strange dose of intense enjoyment, mixed up with about an equal proportion of acute disappointment.

In flying over the valleys and round the hills and mountains of North Wales, there repeatedly glided before their eyes a succession of scenery of a most beautiful description, which, illuminated by the sunshine of heaven, appeared, as they approached each great impending mountain, to be exquisitely improving; until all of a sudden—just as if the pestilential breath of an evil spirit had blown out the tallow candle of their happiness—nothing in this world was left to occupy their senses but the cold chilly air of a damp dungeon rushing across their faces, a strong smell of hot rancid grease and sulphur travelling up their noses, and a loud noise of hard iron wheels, rumbling through a sepulchral pitch-dark tunnel, in their ears.

Hundreds of most excellent people of both sexes, who had been anxiously expecting to see

'The rock—whose haughty brow
Frowns o'er old Conway's foaming flood,'

were grievously chagrined and most piteously disappointed by being told—as, like a pea going through a boy's pea-shooter, they were unintellectually flying through a long dark tube—that they were at that very moment passing it, Straits, Castle, and all. However, the balance of the account current was, on the whole, greatly in their favour, and thus, in due time and in high good humour, all reached Bangor in safety.

It need hardly be said that, early in the morning of the day, or rather of the evening, on which the important operations at the Britannia Bridge were actually carried into effect, every boat that could be engaged, every bus, carriage, waggon, gig, cart, and hack-horse that could be hired in Bangor, Beaumaris, as well as in the neighbouring towns and villages, were in requisition to convey, by repeated trips, the curious to the object of their curiosity, —and certainly on reaching it the picture exhibited was one not very easy to be described.

The first amusing moral that irresistibly forced itself upon us, as our conductor with outstretched whip was endeavouring almost in vain to drive through the crowd, was, that of the many thousands of human beings who at considerable trouble and expense had assembled, more than nine-tenths were evidently wholly and solely absorbed in subjects which, though highly interesting, were alien to the purpose for which they had congregated!

Numbers of persons with heated faces, standing around small tables, allocated in various directions, were intently occupied in quaffing off a beautiful unanalysed pink effervescing mixture, called by its proprietor '*ginger beer*.'

The dejected countenance of Punch's English half-starved dog, as, dead-tired of the gallows scene, he sat exalted on his tiny platform, was strangely contrasted with the innumerable sets of strong grinning Welsh teeth and bright eyes, that in joyous amphitheatre were concentrated upon him. In several spots the attention of stooping groups of 'ladies and gentlemen' horizontally looking over each other's backs, was solely engrossed in watching —what no one passing could possibly perceive—some trick of rude legerdemain upon the ground. On a small eminence the eyes of hundreds, as they stood jammed together, were elevated towards a jaded white-cheeked harlequin, and a very plump, painted-faced young lady in spangled trousers and low evening frock, who, on the elevated stage on which they stood, jumped, kicked with both legs, and then whirled violently on one, until the rustic clown, thoroughly satisfied with the sample, and unable to resist the alluring cymbals and brass trumpet that accompanied it, slowly ascended the ladder, surrendered his penny, and then, with his back turned towards the crowd, descended into a canvas chamber to wait, or rather on a rough wooden bench, to sit, like Patience on a monument smiling at Hope.

Long rectangular booths, open at three sides, appeared filled with people, in great coats and in petticoats, seated around a table, all seriously occupied in silent mastication. In the moving crowd some were evidently searching for the party they had lost, while others, suddenly stopping, greeted friends they had not expected to meet.

Among the motley costumes displayed, by far the most striking was that of the Welshwomen, many of whom were dressed in beautiful gowns protected by frock coats,—their neatly-plaited white caps, surmounted by large black hats, such as are worn elsewhere by men, giving to their faces, especially to the old, around whose eyes the crows'-feet of caution were to be seen deeply indented, an amusing appearance of doubtful gender, which—it occurred to us at the time—the pencil of HB, with its usual wit, might, in illustration of the Epicene policy of the day, very faithfully transcribe. But whatever were the costumes, the ages, condition, or rank of the immense crowd of both sexes through which our old-fashioned vehicle slowly passed, everything that occurred seemed to elicit merriment, happiness, and joy. It was, in fact, a general holiday for all; and as boys out of school make it a rule never to think of their master, so apparently with one consent had the vast assemblage around us good-humouredly agreed together to cast aside the book they had intended to read—to forget the lesson they had purposely come to study.

By the kind attention of one of the Company's servants we were conducted in a small boat half way across the rapid currents of the Menai Straits to the Little Rock, then completely beneath the water—upon which, under the able direction of Mr. Frank Forster, engineer of the line from Bangor to Holyhead, there had been erected (on a base imbedded in pure Roman cement of 62 feet by 52 feet) the Britannia Tower, which, still surrounded by its scaffolding, majestically arose out of the middle of the stream to a height of 230 feet.

This enormous structure, which weighs upwards of 20,000 tons, and which, from being roughly quarried or hewn, displays on the outside the picturesque appearance of natural rock, is a conglomeration of 148,625 cubic feet of Anglesey marble for the exterior—144,625 cubic feet of sandstone for the interior—and 387 tons of cast-iron beams and girders worked in, to give strength, solidity, and security to the mass. The only way of ascending was by a series of ladders, communicating, one above another, with the successive layers of horizontal balks, of which this immense pile of well-arranged scaffolding was composed—and accordingly, hand over hand and step by step we leisurely arose until we reached a small platform 15 feet above the pinnacle of the tower.

The view was magnificent. On the east and west were to be seen glittering in large masses the Irish Sea and St. George's Channel, connected together by the narrow Straits, whose silvery course, meandering in the chasm beneath, was alike ornamented and impeded by several very small rocks and islands, round and about which the imprisoned stream evidently struggled with great violence. Upon two or three of these little islands was to be seen, like a white speck, the humble cottage of the fisherman, who alone inhabited it. About a mile towards the Irish Sea there gracefully hung across the stream, in a festoon, which, in the annals of science, will ever encircle the name of Telford, his celebrated Suspension Bridge, over which a couple of horses, appearing like mice, were trotting.

On the north lay extended a verdant country, surmounted in the direction of the new railroad by the great Anglesey Column, erected by the surrounding inhabitants to the noble Commander of the Cavalry at Waterloo. About two hundred yards beneath this splendid testimonial, and adjoining to a little isolated church, there modestly peeped up a very small free-stone obelisk, erected by the workmen of the tower on which we stood as an humble but affecting tribute of regard to some half-dozen of their comrades, who—poor fellows!—had been killed in the construction of the Britannia Bridge.

On the south the horizon appeared bounded, or rather fortified, by that range of mountains, about forty miles in length, which bear the name of Snowdon, and among which, the loftiest, stands the well-known Patriarch of the group. Between the base of these hills and the Straits was the little wooden city built for the artificers and workmen, its blue slates and whitewashed walls strongly contrasting with each other. In this vicinity we observed, in large masses and patches, the moving multitude through which we had just driven, and who, unsatiated with enjoyment, were still swarming round one object after another, like bees occasionally dispersing only to meet again.

Lastly, close to the shore, on their wooden platform, from which the crowd, by order of Captain Moorsom, R.N., was very properly strictly excluded, there stood, slightly separated from each other, the sole objects of our journey—namely, the two sets of hollow tubes, four in number, which, under the sole superintendence of Mr. Edwin Clark, had been constructed as the aërial passages for the up and down trains across the Straits. Being each 472 feet in length, and being also of the height of an ordinary two-storied dwelling, they all together appeared like a street or row of chimneyless houses half a mile long, built on the water's edge; indeed, if windows and doors had been painted upon them, the resemblance would have been perfect. Of the four lengthy compartments, the two on the eastern extremity, and that on the western end, had been painted red; the remaining one, which in a few hours was not only to be launched but floated down the stream to the very foot of the tower on which we stood, had been finished in stone-colour.

We would willingly conclude our slight panoramic picture by describing the appearance of the moving water gliding past the foot of the tower far beneath; but on going to the edge of the masonry to look down at it, we must confess that we found it to be utterly impracticable to gaze even for a moment at the dizzy scene.

In descending from the eminence we had been enjoying, we paused at 50 feet from the top to inspect the steam-engine and boiler therein inserted for working two hydraulic presses, which principally reposed upon a wall 10 feet 6 inches thick, the other three walls being 7 feet 6 inches in thickness. At 107 feet from the top, and at 103 feet from the water, we again stopped for a few minutes to enter the immense passage in the Britannia Tower, through which—strange to think—trains full of up and down passengers at railway speed are to pass and repass each other. The ends of the tubes from the Anglesey and Carnarvon Towers, reposing far away on the beach, meeting at this point on immense cast-iron plates interposed on the masonry to secure an equal pressure, are not only to be firmly connected together, but by their weight are substantially riveted to the fabric. To the opposite ends of these tubes, the extremities of those passing from the embankment to the two land towers just named are also in like manner to be firmly connected; by which means each aërial gallery will eventually be composed of a single hollow iron beam 1511 feet in length, far surpassing in size any piece of wrought iron-work ever before put together—its weight, 5000 tons, being nearly equal to that of two 120-gun ships, having on board, ready for sea, guns, powder, shot, provisions, crew, flags, captains, chaplains, admiral, and all!

Lastly, to bring the component parts of this not only extended but attenuated mass of iron into vigorous action, or in other words, to enable it to exert its utmost possible strength, Mr. Stephenson has directed that after the component parts of each of the two parallel tubes have, by the process already described, been firmly riveted into one continuous hollow beam, the extremities thereof shall be lowered about 15 inches, by taking away the false keels or foundations, on which in their construction they had purposely been raised. By this simple operation it is estimated that the tube will receive a strength of 30 per cent. in addition to that which it possessed in separate lengths, and without the precise amount of tension so scientifically devised. When thus finally completed, the total length of the bridge will amount to 1833 feet 4 inches.

To enable this enormous mass of thin plate-iron—(the middle of which, as we have stated, is to rest heavily on to that passage through the Britannia Tower to which we have descended)—comfortably to expand itself and contract according to the temperature of the weather—a yawning enjoyment which requires the space of about 12 inches—a number of cast-iron rollers, as well as of balls of gun metal, all six inches in diameter, have been placed on immense cast-iron frames deposited on the land towers and abutments—so that the tubes, like the tide beneath them, may freely flow forwards or ebb backwards at their free will and pleasure, or rather according to the immutable laws of the Omnipotent Power by which they have been created.

On crawling upon our hands and knees through a gap or hole in the masonry of the Britannia Tower, which had been kept open for the purpose of passing through it a stout hawser for hauling to its destination the floating tube, we suddenly perceived at its base lying prostrate immediately beneath us—on a large platform latticed like the grating of a ship, and under which the deep stream was rushing with fearful violence, boiling, bubbling, eddying around, as well as dimpling along the piles that obstructed it—what at the first glance very much resembled the main-sail of a man-of-war stretched out to dry—but which we soon discovered to be a conglomeration of the earth-stained fustian jackets, fustian trowsers, dusty stockings, hob-nailed shoes, red sun-burnt faces and brown horny fingers of a confused mass of over-tired labourers, all dead asleep under the stiff extended bars of the capstan which they had constructed, and at which they had been working.

Although they were lying, what in country parlance is termed ‘ top and tail,’ jammed together so closely that in no place could we have managed to step between them, not a single eye was open, or scarcely a mouth shut. The expression of their honest countenances, as well as of their collapsed frames, plainly told not only how completely they had been exhausted, but how sweet was the rest they were enjoying. In the right hands of several of them, old stumpy pipes of different lengths, also exhausted, were apparently just dropping from their fingers, and while the hot sun was roasting their faces and bare throats, a number of very ordinary blue-bottle flies in search of some game or other were either running down their noses and along their lips to the corners of their mouths, or busily hunting across the stubble of their beards.

Although for some time 'we paced along the giddy footing of the hatches' on which they were snoring, gazing sometimes at them, sometimes at the wild scenery around them, and sometimes at the active element that was rushing beneath, no one of the mass awakened or even moved, and thus, poor fellows! they knew not, and never will know, the pleasure we enjoyed in reviewing them!

On rowing from Britannia rock we had, of course, a full view of the remainder of the masonry, containing altogether no less than 1,500,000 cubic feet of stone, of which this stupendous work is composed. As, however, it would be tedious to enter into its details, we will merely, while our boat is approaching the shore, state, that the towers and abutments are externally composed of the grey roughly-hewn Anglesey marble we have described; that the land-towers, the bases of which are the same as that of the Britannia, are each 198 feet above high-water, and that they contain 210 tons of cast-iron girders and beams.

The four colossal statues of lions—we must not compare them to sentinels, for they are couchant—which in pairs terminate the land ends of the abutments that on each side of the straits laterally support its approaching embankment—are composed of the same marble as the towers. These noble animals, which are of the antique, knocker-nosed, pimple-faced Egyptian, instead of the real Numidian form, although sitting, are each 12 feet high, 25 feet long, and weigh 30 tons. Their appearance is grand, grave, and imposing—the position they occupy being 180 feet in advance of the entrances into the two tubes, which so closely resemble that over the drawbridge into a fortress, that one looks up almost involuntarily for the portcullis.

The net-work of scaffolding, nearly 100 feet high, upon which the short tubes communicating from the Anglesey abutments to the land-tower had been permanently constructed, not only appeared highly picturesque, but was very cleverly composed of large solid balks of timber from 12 to 16 inches square, and from 40 to 60 feet in length.

THE FLOATING OF THE TUBE.

On landing we, of course, proceeded to the long range of tubes, or streets, we have described.

The arrangements which Mr. Stephenson had devised for floating the first of them to its destination were briefly as follows :—

As soon as this portion of the gallery was finally completed, the props upon which it had rested at a height above the wooden platform sufficient to enable artificers to work beneath it, were removed, so as to allow it to be supported only at its two extremities. The result of this trial satisfactorily demonstrated the accuracy of the calculations upon which the tube had been purposely constructed circular at bottom to the height or camber of nine inches, in order that when it assumed its proper bearing it should become perfectly straight—*which it did.*

During its formation a portion of the wooden platform under each of its ends was cut away and the rock beneath excavated, until on either side there was formed a dock just large enough to admit four pontoons, each 98 feet long, 25 feet wide, and 11 feet deep. When these docks were completed the eight pontoons,—scuttled at the bottom by valves which could either let in or keep out the water at pleasure,—were deposited at their posts; and though their combined power of floatage amounted to 3200 tons, the weight of the tube with its apparatus being only 1800 tons, yet, in consequence of the valves being kept open so as to allow the tide to flow in and out, they lay on their bottoms like foundered vessels; and thus it was curious to see crouching, as it were, in ambush beneath the tube a dormant power, only waiting for the word of command, *up and at 'em*, to execute the duty they were competent to perform.

Besides these arrangements, Mr. Stephenson, in pursuance of a plan which had been deliberately committed to paper, had ordered the construction, on the Anglesey and on the Carnarvon shores, as also on stages constructed on piles at the Britannia rock, of a series of capstans, communicating with the pontoons by a set of ropes and hawsers more than two miles in length. Of these the principal were two four-inch hawsers, or leading-strings, between which, like a captive wild elephant between two tame ones, the tube was to be safely guarded, guided, and conducted from its cradle to its position at the feet of the Anglesey and Britannia towers.

These preparations having been all completed, and every man having been appointed to his post, the valves in the eight pontoons were closed, in consequence of which they simultaneously rose with the tide, until their gunwales, like the shoulders of Atlas, gradually received their load.

At this moment the few who had been admitted to the spot watched with intense anxiety the extremities of the tubes, which, from the severe pressure they had been inflicting, had, in a slight degree, forced their way into the wooden balks that supported them. By degrees this pressure was observed perceptibly to relax, until a slight crack, and then a crevice, was seen to exist between the old points of contact. In a few seconds this crevice was converted into daylight, amidst a general whisper of exultation announcing, 'IT'S AFLOAT!' The tube, however, was still firmly retained in its dock by two conflicting powers—namely, one set of hawsers, maternally holding it to the quiet home on which it had been constructed—and another set from the shore diametrically opposite, hauling it outwards to its destiny.

At this moment we ascended, by a long ladder, to the top of the tube, and had scarcely reached it when Mr. Stephenson very quietly gave the important word of command—*Cut the land attachments!* Some carpenters, all ready with their axes, at a few strokes nearly severed the strands, and, the tension from the opposite hawsers bursting the remainder, the long street, upon whose flat roof we stood, slowly, silently, and majestically moved into the water.

As the two extremities of the floating tube had been in allignment with those of the tubes on each side, which of course remained stationary, and whose roofs were loaded with well-dressed spectators, its advance was as clearly defined as that of a single regiment when, leaving its division to stand at ease, it marches by word of command from the centre out in front of its comrades.

Upon the deck or roof of the tube, which we may observe had no guard or railing, there was nailed Mr. Stephenson's plan, exhibiting the eight positions or minuet attitudes which the floating monster was to assume at different periods of its voyage; and, as it had 100 feet to proceed before its first change, we had leisure to gaze upon the strange interesting scene that surrounded us.

From the lofty summit of the Britannia Tower, surmounted by the Union Jack, to those of the Anglesey and Carnarvon Towers on either side of it, were suspended, in two immense festoons, flags of all colours and of all nations. Every vessel at anchor, every steamer under weigh, as well as several houses on shore, were similarly ornamented. At different points on each coast, and especially upon every eminence, were congregated large variegated masses of human beings. The great green woods of Carnarvon seemed literally swarming alive with them, and, to add to the audience, a large steamer—arriving almost too late—as it scuffled to a safe position, exhibited a dense mass of black hats and showy bonnets, enlivened by a brass band, which was not unappropriately playing 'Rule *Britannia*,' the breeze wafting along with it the manly, joyous song of the sailors who, at the capstans on the opposite shore, were cheerily hauling in the hawsers upon which, for the moment, the thread of our destinies depended.

On arriving at Position No. 2, it became necessary to exchange the mechanical power by which the tube had been forced forwards, for that of the tide, which was to carry it end foremost down the stream to its goal. As, however, this latter power—to say nothing of a strong breeze of wind which drove the same way—would have propelled the lengthy mass more than twice as fast as it had been declared prudent it should proceed, a very strong power, by means of a small capstan, was exerted in each set of pontoons, to compress between wooden concentric clamps the guide-hawsers, by which contrivance the pace was regulated with the greatest possible precision. This most important duty was confided to, and executed by, two volunteer assistants, Mr. Brunel and Mr. Locke (we rank them alphabetically); and although the whole scene of the flotation was one of the most interesting it has ever been our chequered fortune to witness, there was no part of it on which we gazed, and have since reflected, with such unmixed pleasure, as the zeal and almost over-anxiety with which Mr. Stephenson's two competitors in fame stood, during the whole operation, intently watching him, until by either mutely raising his arms horizontally upwards, or in like manner slowly depressing them, he should communicate to them his desire that the speed might be increased or diminished.

But besides regulating the speed, it was repeatedly necessary, especially at the points we have enumerated, slightly to alter the position of the tube by means of capstans, often working together with combined powers on different points of the shores. Orders to this effect were silently communicated by exhibiting from the top of the tube large wooden letters, and by the waving of flags of different colours, in consequence of which the men of the distant capstans belonging to the letters telegraphically shown, were, at the same moment, seen violently to run round as if they had suddenly been electrified. Indeed at one point the poor fellows were all at once thrown upon their backs, in consequence of the rupture of the capstan-stop.

The duties of Captain Claxton—whose scientific and nautical acquirements had previously been evinced by floating the Great Britain at Dundrum—were highly important. Besides the experienced opinions he had contributed, he had sole command of the whole of the marine force, and accordingly from the top of the tube he continually communicated through his trumpet his orders to various small boats which, as floating aide-de-camps, attended upon him.

As he was getting ashore in the morning, we happened to see one of his crew, by suddenly pulling in the bow-oar, strike him so severely on the forehead that the blood instantly burst forth, as if to see who 'so unkindly knocked.' In half-a-dozen seconds, however, his pocket-handkerchief was tied over it, and he was giving his orders if possible more eagerly than before.

'*Jack!*' said a sailor from another boat, as with a quid in his cheek he slowly walked up to the coxswain, '*what's the matter with the Cappen's head?*'

'*A hoar struck him*,' replied the sailor to his brother 'blue-jacket,' who at once appeared to be perfectly satisfied, as if he professionally knew that it was in the nature of an oar to do so.

When the tube was at about the middle of its transit, a slight embarrassment occurred which for a few minutes excited, we afterwards were informed, considerable alarm among the spectators on shore. In one of the most important of our changes of position, a strong hawser, connecting the tube with one of the capstans on the Carnarvon beach, came against the prow of a fishing-boat purposely anchored in the middle of the stream by a chain, which so resolutely resisted the immense pressure inflicted upon it, that the hawser was bent into an angle of about 100 degrees. The coxswain of a gig manned by four hands, seeing this, gallantly rowed up to the boat at anchor, jumped on board, and then, with more zeal than science, standing on the wrong side of the hawser, immediately put a handspike under it to heave it up. *That man will be killed*—said Mr. Stephenson very quietly. Captain

Claxton vociferously assailed him through his trumpet, but the crew were Welsh; could not understand English; and accordingly the man, as if he had been applauded, exerting himself in all attitudes, made every possible exertion not only to kill himself but his comrades astern, who most certainly would also have been nearly severed by the hawser had it been liberated; but a tiny bump or ornament of iron on the boat's head providentially made it impossible, and the hawser having been veered out from a shore, the tube instantly righted.

The seventh movement brought the foremost end of the tube about 12 feet past the Anglesey Tower, and the rear end being now close to its destination, the hook of an immense crab or pulley-block passing through a hole purposely left in the masonry of the Britannia Tower was no sooner affixed to it than the workmen at the capstan on piles, whom we described as asleep, instantly ran round, until the tube was by main strength dragged—like the head of a bullock in the shambles—to a ring from which it could not possibly retreat. By a combination of capstan-power on the north shore, the foremost or opposite end was now drawn backwards until it came to the edge of the Anglesey Tower; and although we were aware that the measurements had of course been accurately predetermined, yet it was really a beautiful triumph of Science to behold the immense tube pass into its place by a windage or clear space amounting, as nearly as we could judge it, to *rather less than three-quarters of an inch.*

The tube having now evidently at both ends attained its position over the stone ledge in the excavation that had been purposely constructed for it, a deafening—and, to us, a deeply-affecting—cheer suddenly and simultaneously burst out into a continuous roar of applause from the multitudes congregated in all directions, whose attention had been so riveted to the series of operations they had been witnessing, that not a sound had previously escaped from them; nor had they, in any place, been seen to move from the spots at which they either stood or sat.

Mr. Stephenson took no notice whatever of this salute; indeed we much question if he even heard it, for his attention was intently occupied in giving to his able and confidential assistant, Mr. Wild, directions respecting the final adjustment of the temporary fastenings by which the tube was to be retained; but the crowd of spectators —like that at a theatre when the curtain of the afterpiece drops—were already seen hurrying away in all directions, by steam, by boats, by carriages, and on foot, until, in the brief course of an hour, both coasts were clear. The tide, however, during the operations we have described had become high, had turned, and was now beginning to be violent; the valves therefore having been partially drawn up, the pontoons, as they gradually filled, sank, until the widely-separated ends of the tube slowly descended to their respective shelf or ledge on each tower; and the discarded power that had successfully transported the vast gallery across the water then floating away with the stream—gently transferred from one element to another—it was thus left in the aëriform position it had been planned to occupy!

During the operations we have detailed there were, of course, made by the spectators of both sexes a variety of observations of more or less wisdom, of which our limits will only allow us historically to record a single sample.

'*Dear me!*' said an old gentleman, as the tube when it first swung across the Straits was in perspective seen approaching the platform on which he sat, and which was immediately in front of the awful chasm between Britannia and Anglesey Towers, '*they have surely been and made it too* SHORT; *they must put a bit* ON!' As soon, however, as, veering round, it approached him broadside foremost, he whispered, '*I'm quite sure it's too* LONG; *they'll have to cut a piece* OFF!'

A lady said to her companion, '*Mr. Stephenson appeared dreadfully excited during the passage! Didn't you observe how he kept continually stretching out his arms, raising them up and then sinking them down in this way?*' (suiting her words to the actions by which the speed of the voyage had calmly been regulated). '*But no wonder he was so agitated!*'

The Company's servants were engaged until long after sunset in securing and placing in safety the various materials, &c., that had been in requisition during the day, and it was not till past midnight that, over-tired, they managed one after another to retire to rest.

On the following morning, after we had bidden adieu to the hospitable inmates of a small wooden habitation, beneath the Anglesey Tower, in which we had been very kindly received, we had occasion to pass near to a stand which had purposely been constructed in a peculiarly advantageous position, to enable the Directors of the Chester and Holyhead Railway to witness the operation. Upon the centre bench of this platform,—the ground far around which was partially covered with bits of orange-peel, greasy papers that had contained sandwiches, and other scraps, indicative of an intellectual feast that was over,—we observed, reclining entirely by himself, a person in the easy garb of a gentleman, who appeared to be in the exquisite enjoyment of a cigar, whose white smoke in long expirations was periodically exuding from his lips, as with unaverted eyes he sat indolently gazing at the aërial gallery before him. It was the father looking at his new-born child! He had strolled down from Llanfairpwllgwyngyll, where, undisturbed by consonants, he had soundly slept, to behold in sunshine and in solitude that which during a weary period of gestation had been either mysteriously moving in his brain, or like a vision —sometimes of good omen and sometimes of bad—had by night as well as by day occasionally been flitting across his mind.

Without, however, presuming to divine, from the rising fumes of a cigar, the various subjects of *his* ruminations, we will merely confess that, on looking up from our boat, as it glided away, at the aërial gallery he was contemplating, *we* were astonished to find ourselves very much in the frail predicament of mind of the old gentleman of yesterday whose emotions we so accurately delineated—for when the tube was lying on the Carnarvon shore we certainly fancied that it looked too heavy and too high for its object, whereas it now appeared almost too light and too low: in short, it had assumed the simple appearance which, in principle, it had been designed to bear—that of a rectangular hollow beam; and although it had in fact annulled the awful chasm between the Anglesey and Britannia Towers, nevertheless, by exactly measuring it, it now appeared considerably to have increased it!

Moreover, in viewing this low narrow passage—only 15 feet by 30—which, without cuneiform support, was stretching half across the Menai Straits—(it has been quaintly observed by Mr. Latimer Clark, in his clever pamphlet, that if this single joint of the tube could be placed on its tiny end in St. Paul's Churchyard, it would reach 107 feet higher than the cross)—it seemed surprising to us that by any arrangement of materials it could possibly be made strong enough to support even itself, much less heavily-laden trains of passengers and goods, flying through it, and actually passing each other in the air, at railway speed. And the more we called reason and reflection to our assistance, the more incomprehensible did the mystery practically appear; for the plate-iron of which this aërial gallery is composed is literally *not so thick* as the lid, sides, and bottom which, by heartless contract, are *required* for an elm coffin 6½ feet long, 2¼ feet wide, and 2 feet deep, of strength merely sufficient to carry the corpse of an emaciated, friendless pauper from the workhouse to his grave!

The covering of this iron passage, 1841 feet in length, is literally not thicker than the hide of the elephant! Lastly, it is scarcely thicker than the bark of the 'good old English' oak; and if this noble sovereign, notwithstanding the 'heart' and interior substance of which it boasts, is, even in the well-protected park in which it has been born and bred, often prostrated by the storm, how difficult is it to conceive that an attenuated aërial hollow beam, no thicker than its mere rind, should by human science be constituted strong enough to withstand, besides the weights rushing through it, the natural gales and artificial squalls of wind to which throughout its immense length, and at its fearful height, it is permanently to be exposed!

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CHAPTER IV.

RAISING THE TUBES.

Hydraulic Press.—Although the tube, resting at each end upon the ledge or shelf that had been prepared for it, had been deposited high enough to allow an ordinary boat to row under it, yet the heaviest job still remained—that of raising it about 100 feet to its final resting-place. This operation, which might be compared to lifting the Burlington Arcade to the top of St. James's Church—supposing always that the said church arose out of very deep, rapid water—was, as we have already stated, to be performed by the slow but irresistible agency of hydraulic power; and as one of the presses used is said not only to be the largest in the world, but the most powerful machine that has ever been constructed, we will venture to offer to those of our readers who may never have reflected upon the subject, a brief, homely explanation of the simple hydrostatic principle upon which that most astonishing engine, the hydraulic press, invented, or rather rendered practicable by Bramah, is constructed.

If the whole of the fresh water behind the lock-gates of a canal communicating directly with, say the German Ocean, were to be suddenly withdrawn, it is evident that the sea-side of the gates would receive water-pressure, and the other side none.

Now if a second set of gates were to be inserted in the salt-water at a short distance, say one foot, in front of the old ones—(the water between both sets of gates remaining at the same sea-level as before)—many, and perhaps most people, would believe that the pressure of the German Ocean against the new gates would of course relieve, if not entirely remove, the pressure against the old ones,—just as a barrier before the entrance of a theatre most certainly relieves those between it and the door from the pressure of the mob without.

This opinion, however, is fallacious; for, supposing that the new gates were by machinery to be firmly closed, the foot of salt-water included between them and the old gates would not only continue to press exactly as heavily against the latter as the whole German Ocean had previously done, but by simultaneously inflicting the same amount of pressure against the inside of the new gates as the ocean was inflicting on their outside, the pressure of this imprisoned single foot of water would so accurately counterpoise that of the whole wide, free ocean, that if the machinery which had closed the new gates were suddenly to be removed, they (the new gates) would be found, as it were, vertically to float between the two equal pressures!

But, anomalous as this theory may appear, it is beautifully demonstrated by the well-known fact, that if water be poured into a glass syphon, of which one leg is, say an inch in diameter, and the other, say a foot, the smaller quantity will exactly counterbalance the greater, and the water will consequently, in both legs, rise precisely to the same level; and this would be the case if one leg of the syphon were as large as the German Ocean, and the other as small as the distance between the two sets of lock-gates we have just described—indeed it is evident that, if a hole were to be bored through the bottom of the new gates, a syphon would instantly be formed, of which the ocean would be one leg and the foot of included salt-water the other.

Now Bramah, on reflection, clearly perceived that from this simple principle in nature a most important mechanical power might be obtained; for if, say five ounces of water in a small tube, can be made to counterbalance, say a hundred thousand ounces of water in a large one, it is evident that, by the mere substitution in the bottom of the larger tube of a flat solid substance instead of the water, a pressure upon the body so inserted of very nearly a hundred thousand ounces would be inflicted by the application of only five ounces!—and—as this pressure would of course be proportionately increased by increasing the height, or in other words the *weight* of water in the smaller tube—Bramah therefore further reasoned that, if, instead of adding to the quantity of water in the smaller tube, the fluid therein were to be ejected downwards by a force-pump, the pressure upwards in the larger tube would proportionately be most enormously increased; and *à fortiori*, as, in lieu of the old-fashioned forcing-pump, the power of steam has lately been exerted, our readers will, we believe, at once perceive that, if the instrument which holds the water could but be made strong enough, the pressure which might be inflicted within it by a few gallons of water might almost be illimitable.

The *principle* of the hydraulic press having been above faintly explained, the power and dimensions of the extraordinary engine of this nature, which has been constructed by Messrs. Easton and Amos, of Southwark, for raising the Britannia tubes, may be thus briefly described.

The cylinder, or large tube, of the syphon, which is 9 feet 4 inches in length, 4 feet 10 inches in diameter, and which is made of cast-iron 11 inches thick, weighs 16 tons. The piston, termed *the Ram*, which, pressed upwards by the water, works within it, is 20 inches in diameter. The whole machine complete weighs upwards of 40 tons. The force-pump barrel communicates with a slender tube or passage about the size of a lady's smallest finger, which, like the touch-hole of a cannon, is drilled through the metallic side of the cylinder; and thus, although the syphonic principle really exists, nothing appears to the eye but a sturdy cast-iron cylinder of about the length of a 24 lb. cannon, having the thickness of metal of a 13-inch mortar.

From the above trifling data it will be evident that, leaving friction and the weight of the ram out of the question, the lifting power of this machine must exceed the force applied to the force-pump in the same proportion that 1⅛-inch diameter bears to a diameter of 20 inches—which in figures amounts to about 354 to 1; and as the two 40-horse steam-engines which are to be applied to the touch-hole for compressing the water in the smaller tube would, it has been calculated by Mr. Latimer Clark, be sufficient to force the fluid more than five times as high as the top of Snowdon, or 5000 feet higher than the summit of Mount Blanc, our readers have only to increase the force in this proportion to become sensible of the extraordinary power which the hydraulic press of the Britannia Bridge is capable of exerting for the purpose of raising its tubes. In short, the power is to the weight of the tubes as follows:—

	Tons.
Weight of one of the largest tubes . .	1800
Lifting-power of the hydraulic press .	2622

The mode in which this enormous power is practically exercised is as follows:—

The hydraulic cylinder, standing erect, like a cannon on its breech, on two stout wrought-iron beams bolted to each other, is, together with its steam-boiler, securely fixed in the upper region of the Britannia Tower, 148 feet above the level of its base, and about 45 feet above that to which the bridge is to be raised.

Around the neck of the iron ram or piston, which protrudes 8 inches above the top of this cylinder, there is affixed a strong horizontal iron beam 13 feet in length, resembling the wooden yoke used by milkmaids for carrying their pails, from the extremities of which there hang two enormous iron chains, composed of eight or nine flat links or plates, each 7 inches broad, 1 inch thick, and 6 feet in length, firmly bolted together. These chains (which, in order to lift the tube to its destination, are required to be each 145 feet long) weigh no less than 100 tons—which is more than double the weight of the equestrian statue of the Duke of Wellington, lately erected in Hyde Park—commonly regarded as one of the heaviest lifts ever effected: and certainly, when from the giddy region of the Britannia Tower, in which this hydraulic machinery, like the nest of an eagle, has been deposited, the stranger, after looking down upon the enormous weight of iron not only to be supported but to be raised, compares the whole mass with the diameter of the little touch-hole immediately before him, through which the lifting-power has to pass—and when he reflects that the whole process can, with the greatest ease, be regulated and controlled by a single man, it is impossible to help feeling deeply grateful to the Divine Power for an invention which, at first sight, has more the appearance of magic than of art.

As soon as all adjustments were prepared, and the boiler was sufficiently heated, the great piston, under the influence of severe pressure upon the water beneath it, began slowly, like a schoolboy's 'jack-in-the-box,' to emerge from the cylinder, and, apparently regardless of the enormous weight that oppressed his shoulders, he continued steadily to rise, until in about thirty minutes he lifted the tube 6 feet, and, as he could raise it no higher, the huge chains beneath were immediately secured by a powerful vice or 'clams' at the foot of the press. By letting off the water, which of course relieved the pressure beneath the piston, it descended, by its own gravity, to the point from which it had started, where the chains being again affixed to its yoke—an operation which requires about half an hour—it again, by the vitality of steam, lifted its weight another six feet; and, as the other end of the tube was simultaneously treated in a similar way, the whole was progressively raised nearly 30 feet, when, by the bursting of the largest of the hydraulic presses—a contingency which, from the faithless crystalline character of *cast* iron, it is utterly impossible for Science to prevent—the ponderous mass unexpectedly fell through a space of seven inches—an awful *phenomenon* to witness—until it was gradually stopped by the packing, timber, and brickwork which had cautiously been under-built during its ascent—and from which it has since been raised to a point a few feet above its ultimate position, where two strong iron beams being placed beneath, it was triumphantly lowered to its final resting-place, to be the aërial highway of the public!

CHAPTER V.

MR. FAIRBAIRN'S CLAIMS.

DURING the brief inspection which we made of the Britannia Bridge we can truly say, that, far from feeling a desire to award to Mr. Robert Stephenson the whole merit of the wonderful piece of mechanism before us, we repeatedly paused not only to reflect but to regret how little the Public would probably ever think of, or care for, the assistant-engineers, overseers, skilled artificers, and honest steady labourers, by whose zeal, assiduity, and personal courage the heavy job had practically been completed. 'Who,' we asked ourselves, 'will ever care to thank those who, surrounded by the torrent, toiled by night as well as by day at the foundation of the Britannia Tower? When that beautiful structure of scaffolding, composed of 570,000 cubic feet of timber, upon which the land-tubes have been constructed, shall be removed, who will ever expend a thought of kindly recollection on those by whose skill it was devised, or by whose enduring patience it was at no trivial risk constructed? What reward, beyond their bare wages, will the superintendents of the various departments of the work ever receive for the anxiety they suffered for several years, under a weight of responsibility which, while it promised for success no rewards, threatened for failure the severest description of moral punishment?' And, lastly, we said to ourselves, as on the top of the tube we stood over the holders-up and rivet-boys, who, stuffed together into flues in the painful attitudes we have described, were working immediately beneath our feet, 'Who, in flying across the Menai Straits, will ever feel that he is indebted for his life to the care and attention with which these poor fellows are patiently riveting, one after another, the millions of bolts by which he is to be safely transported in his aërial transit?'

Impressed with the justice of these feelings, we were therefore not only strongly predisposed to award to every person, however humble, who had been connected with this great work, the full amount of credit due to him for the particular portion of it which he individually executed, but we were ready almost to admire, and at all events to excuse, that *esprit de corps* which invariably induces every separate department to consider its labours to have been of the greatest importance; indeed, there is no better qualification in a subordinate than to be what is commonly called 'proud of his work.' If, therefore, Mr. Fairbairn, Mr. Hodgkinson, and Mr. Clark had, either collectively or individually, endeavoured to assume a larger share of merit than was intrinsically due to the important preliminary investigations they had conducted, we should indulgently have smiled at their boyish zeal, and even if we could not have approved, we should most certainly have refrained from noticing it; but in the serious appeal, or rather demand, which Mr. Fairbairn has deemed it advisable to make to the public, he has not only claimed merit which is the property of his colleagues, but has, although he occasionally renounces it, claimed for himself that of the invention itself! He has therefore forced us, as indeed every one who takes a mechanical interest in the subject, dispassionately to weigh the value of the claims he has urged, and at all events to hear the cause in which he voluntarily appears as the plaintiff.

The investigation ought to be an easy one, and so indeed it is; nevertheless we regret to say, that Mr. Fairbairn with very great ingenuity has riveted together facts, documents, and assertions which, when logically separated and compared with the evidence taken before the House of Commons, confuse, confound, and condemn each other.

We will endeavour by very brief extracts to arrange the case as fairly as possible. Mr. Fairbairn in his book states—

'That Mr. Stephenson conceived the original idea of a huge tubular bridge to be constructed of riveted plates and *supported by chains.*'—p. 2.

'He [Mr. S.] never for a moment entertained the idea of making the tube self-supporting. The wrought-iron tube, according to his idea, was, indeed, entirely subservient to the chains.'—p. 3.

'The form which the Menai Bridge now has, was advocated by me alone.'—p. 31.

'I was anxious to clear the tube of the incumbrance of chains, which it must be borne in mind were intended from the first, not only for the support of the tubes, but for the purpose of carrying them forward from the platform on which they were to be built across their respective spans to their final positions on the piers.'—p. 48.

'Mr. Stephenson was present at one or two of the experiments afterwards made on the model-tube, and, after witnessing them, his fears were in a great degree removed; he *then* determined to abandon the use of auxiliary chains, and from that time, October, 1846, to the completion of the Conway Bridge, he relied with confidence on the strength of the tube itself, and attached a proper degree of importance to the results of *my* earlier experiments.'—p. 50.

The above-quoted assertions are all dated by Mr. Fairbairn '1849;' and as in the last of them he distinctly points out that it was in October, 1846, that Mr. Stephenson abandoned the use of auxiliary chains 'for the form which the Menai Bridge now has,' which beamlike form Mr. Fairbairn positively asserts '*was advocated by him alone*,' it becomes necessary that we should refer to the following minutes of evidence which on the 5th and 6th of May, 1845, was given before the Committee of the House of Commons 'on Chester and Holyhead Railway Bill, Group 2, Thomas Henry Sutton Sotheron, Esq., in the Chair.'

'ROBERT STEPHENSON, ESQ., *called; examined by* MR. ROBINSON.

'You are the engineer of the intended line of railway?—I am.

'Is there to be a bridge of 104 feet high and with the arches of 450 feet span?—There is.

'Do you consider that a practicable and safe mode of crossing the Menai under the circumstances?—Yes, I do.

'Is it not an arch on the plan of the Southwark Bridge?—No. Perhaps I may at once explain to the Committee the idea I have adopted. I conceive a tube. Supposing a wrought-iron tube to extend across the Straits, and that tube to have, we will say, 25 feet diameter to hold a line of railway, and the line of railway would run inside of it. In addition to that we should have to erect a chain platform *for the purpose of the building*. Then the question would arise whether the chains would be allowed to remain, or whether they would be taken away down. My own opinion is, *that a tube of wrought-iron would possess sufficient strength and rigidity to support a railway-train.*

'Is this mode of construction quite original?—It is.

'It is your own view?—Yes, meeting the contingencies which have been put upon me by Government engineers.

'How would you place it in the position you mean it to occupy?—There will be a platform erected and suspended by the chains, just the same as they bind an iron vessel.

'I wish to ask you whether this is your own suggestion?—It is entirely.

'From the experiments you have made, and from the inquiries you have also made, are you satisfied that that suggestion of yours is a practicable and safe one?—I am not only satisfied that it is practicable, but I must confess that I cannot see my way at present to adopting anything else.

'And in what way do you propose to unite the plates?—In the same way as the iron that is used in a ship is united.

'It will be one mass of iron?—Yes, a smooth tube made of wrought-iron the same as a ship.

'A succession of plates united together?—Yes, with rivets.

'No rods?—No rods.

'Running the whole length?—No; there may be what is termed angle irons.

'What would be the diameter of each of these tubes?—I should make them elliptical, 25 feet in height, and just wide enough to hold one line of railway trains.

'What would be the distance below without support?—450 feet.

'In each of them?—Yes.

'You have not made up your mind as to the safety of dispensing with the chains?—No, I have not.

'It would be impossible to do so until it is constructed, would it not?—I would rather leave that, because I would make the design so that the chains might either be taken away or left, and during the construction we should have ample opportunity of ascertaining whether we could safely take away the chains or not.

'There would be no great advantage from taking away the chains?—No, only it would make it more costly if they remained: they would be applicable to other purposes, and they would cost from 30,000*l.* to 40,000*l.*

'You have no doubt, Mr. Stephenson, that the principle applied to this great span will give ample security to the public?—Oh! I am quite sure of it.

'And you said that although you thought that an iron tube of the thickness you have mentioned, viz. $\frac{7}{8}$ of an inch above and below, and a little less on the two sides, *will bear any weight that is likely to be put upon it* in the shape of trains? —Yes.

'You feel perfectly confident upon that point?—Yes, I feel perfectly confident; but with a view to remove any doubts upon that point, I feel it necessary to make a series of experiments, not that it will convince me more than I am at present, but that it shall convey confidence to the Board of Directors under whom I am acting.'

It has since been stated in a memorandum written by Mr. Stephenson,

'that the Committee before whom he was examined, alarmed at his project, were inclined to hesitate about passing the bill; that their apprehensions were mainly appeased by General Pasley saying that the chains were not necessarily to be removed; and that, as the bill would evidently have been lost had he (Mr. Stephenson) insisted on removing them, he modified his opinion as above quoted.'

Our readers will now observe whether or not such a necessity really existed.

'General PASLEY was called in and examined by the Committee.

. . . .

'On the whole, therefore, General Pasley, you think a bridge built on the plan proposed by Mr. Stephenson would give ample security for trains passing there?—I feel convinced it would.

'And you believe it to be a practicable plan?—Quite so.

'But you do not advise the removal of the chains?—I do not: I see no advantage in it.

'Do you think there would be any hazard in removing them?—I think it would be better to leave them.

'It is difficult to answer the question until the bridge is actually built, is it not?—Yes.

'Previously to a railway being opened, it is usual to send you to ascertain the security of the railway, is it not?—Yes.

'And therefore you probably will be sent down to ascertain the security of this bridge before the railway is open to the public?—Yes.

'And could these chains be removed without the sanction of the Government?—I do not know. I do not see any objection to their being there. *I should recommend their not being removed.*'

Without offering any opinion on the foregoing allegations and evidence, we will at once proceed to the causes of Mr. Fairbairn's retirement from the service of the Chester and Holyhead Railway Company, and of his publication of the large costly volume before us. The details had best be explained by himself.

Mr. Fairbairn publishes two letters (a portion of one of them in italics) from Mr. Stephenson, of which the following are extracts:

1. '23rd August, 1847.—I was surprised at your letter this morning, asking me if I wished you to take charge of the floating and lifting. *I consider you as acting with me in every department of the proceedings.*'

2. '7th February, 1848.—My dear Sir,—I only reached London this morning from Newcastle, when I received your previous note, upon which I will speak to you verbally. You allow your feelings to get the better of you respecting Mr. Hodgkinson, and I think improperly; for it is clear that his experiments alone have given the true law that governs the

strength of different sized tubes. Both your plan and my own for calculating the strength are empirical; but Hodgkinson's experiments and his deductions from them give the true law with remarkable consistency.

'Yours faithfully, ROBERT STEPHENSON.'

'But,' says Mr. Fairbairn, 'what chiefly led me to this decision [his retirement] was the position assumed by Mr. Stephenson: his public misrepresentation of the position I held under the Company, and his endeavour to recognise my services as the labours of an *assistant* under his control, and acting entirely under his direction. Had Mr. Stephenson in his public address done me the justice to state my independent claim to some of the most important principles observed in the construction of the tubes, I might perhaps have continued my services until the final completion of the whole undertaking, and most assuredly, this work [Mr. F.'s book] would never have come before the public.'—p. 171.

'Upon the completion, continues Mr. Fairbairn, 'of the first Conway tube it was resolved by the gentlemen and inhabitants of the neighbourhood to entertain Mr. Stephenson at a public dinner, which should at the same time celebrate the satisfactory conclusion of this great engineering triumph.'—p. 172. . . . 'In the course of his address at the Conway entertainment Mr. Stephenson is reported to have made the following observations:—' "I believe it will be expected of me—indeed I should feel it improper if I were to omit on this occasion detailing very succinctly a few facts with reference to the rise and progress of the idea which led to the construction of tubular bridges; because in doing so it will not only afford me an opportunity of explaining to you precisely what the origin was, but it will also give me the opportunity of expressing my obligations to those who have so largely aided me in bringing about the result which we are met to commemorate." '—p. 174.

The following are the '*observations*' of which Mr Fairbairn complains:

'As soon as the bill was obtained, and it became time to commence, I obtained the consent of the Directors to institute a very laborious and elaborate and expensive series of experiments, in order more thoroughly to test experimentally the theory I had formed, and also to add suggestions for its full development. It was then that I called in the aid of two gentlemen, eminent both of them in their profession—Mr. Fairbairn and Mr. Hodgkinson. They had both distinguished themselves for elaborate series of experiments on cast-iron bridges; and although this was a different material, still from their accomplishments and skill they were well qualified to aid me in my research. They heartily went into it; and the result is what you now see under the walls of your venerable old castle. But having mentioned these two names, there is another gentleman that I wish to call to your notice—a gentleman to whose talents, to whose zeal and ability from the commencement of this undertaking, I am much indebted; and indeed the full development of the principle of tubular bridges is by no means in a small degree indebted to him—I allude to my assistant, Mr. Edwin Clark. He has been my closet companion from the commencement of the preliminary investigation. No variation or inconsistency in the experiments eluded his keen perception: he was always on the look-out for contingencies that might affect the success—though not the principle, still the success—of the undertaking; and he and the other gentlemen whom I have just named are the three to whom I feel deeply indebted for having brought the theory I first broached to such perfection; and I thus publicly tender them my acknowledgments.'—p. 176.

Two days after this speech Mr. Fairbairn communicated to Mr. Stephenson his resignation, the reasons for which he explains in his book as follows:—

'Mr. Stephenson [in his speech at the Conway dinner] states that he called in the aid of Mr. Hodgkinson and myself at the same time. Now it is essential to the proof of my claims that this assertion should be explicitly contradicted. It was I, and not Mr. Stephenson, that solicited Mr. Hodgkinson's co-operation, and this was not done until I had been actively engaged for several months in my experimental researches, and after I had discovered the principle of strength which was offered in the cellular top, and not only proved the impracticability of Mr. Stephenson's original conception, but had given the outline of that form of tube which was ultimately carried into execution.

'When Mr. Stephenson had made up his mind to claim in the manner he did the whole merit of the undertaking, it is not difficult to understand his reason for giving Mr. Clark—his own assistant—so prominent a position.'—p. 177.

As it is perfectly immaterial to us what feelings Mr. Fairbairn may entertain or express as respects his colleagues, Mr. Hodgkinson and Mr. Clark, we have no observations to offer on that point; but as it appears from the foregoing extracts that Mr. Fairbairn complains of Mr. Stephenson having 'endeavoured to recognise his services as the labours of an assistant under his control,' it is necessary to state, or, if Mr. Fairbairn prefers it, unequivocally to admit, that Mr. Stephenson—having engaged Mr. Fairbairn to make a series of experiments for the purpose of determining the best form of tube and the law of its resistance to fracture—having on the 13th of May, 1846, further recommended to the Board that Mr. Fairbairn should be engaged 'to superintend with him the construction and erection of the Conway and Britannia bridges'—and having still further recommended that a salary of 1250*l.* per annum, which Mr. Fairbairn enjoyed for more than two years, should be granted to him: all of which appointments and recommendations the Board of Directors 'at Mr. Stephenson's recommendation sanctioned and ordered'—certainly *did* consider Mr.

Fairbairn as an 'assistant under his control.' The Directors of the Company, rightly or wrongly, entertained the very same opinion; and as Mr. Fairbairn in his Letter of Resignation above referred to had styled himself '*engineer along with yourself* for the tubular bridges,' the Board deemed it proper to direct that in reply to that letter the following very significant minute should be transmitted through their engineer-in-chief to his *in*subordinate:—

'Copy. *June* 7, 1848. Read—Letter from Mr. Fairbairn, dated 22nd May, tendering his resignation of the appointment of *assistant* to Mr. Stephenson in the construction of the tubular bridges. Resolved—That Mr. Fairbairn's letter be referred to Mr. Stephenson with a request that *he* accept the proffered resignation of Mr. Fairbairn; and that, inasmuch as the appointment was originally made by *him* (Mr. Stephenson), he do so in such terms as he may think proper.'

All this seems strong—but strange as well as strong to add—Mr. Fairbairn, in the preface of his own book, himself acknowledges 'the honour which he felt in having been selected *by Mr. Stephenson* as the fittest person to elucidate the subject and conduct the inquiry.' Moreover, in addition to 'the *honour*,' Mr. Fairbairn enjoyed the exquisite *advantage* of supplying from his boiler-manufactory at Millwall all the iron which, between his meals, he luxuriously crushed, broke, and bruised in experiments, the whole of which cost the Company no less than 6000*l.*; besides which it appears from the Board's minutes that Mr. Fairbairn allotted to himself a most lucrative contract for the construction of the iron-work of the bridges; which contract, to the great displeasure of the Directors, he immediately sold at a profit of several thousand pounds to Mr. Mare of Blackwall;

in short, Mr. Fairbairn, like every eminent tradesman, naturally enough worked for money, and not for fame; and if the Company had proposed to have paid him in the latter coin, he would, no doubt, have very laconically corrected their mistake. Leaving therefore Mr. Stephenson completely out of the case, may not Mr. Fairbairn be fairly asked whether he conceives that the credit of the investigation he was engaged to make legitimately belongs to the Board of Directors, who paid for the experiments, or to the individual who was paid for conducting them?

If Mr. Fairbairn, after having expended 10,000*l.* in searching for coals or in boring for water, had in either or in both cases been successful, would he have claimed the merit of the result for himself, or would he have given it to the honest foreman, who, at wages of three guineas a week, had been engaged by him to conduct the expensive investigation he had proposed?

Mr. Fairbairn's third and last complaint is, that Mr. Stephenson has withheld from him the sole credit of the final adoption of rectangular tubes, with rectangular flues in the tops and bottoms thereof. Now Mr. Hodgkinson very stanchly maintains that it was *he* who first recommended rectangular tubes. It however appears, from the following extracts from Mr. Fairbairn's own statements, and written reports to Mr. Stephenson, as published in his book, that these discoveries, instead of belonging to any one of the triumvirate, were the natural sequences of the investigation recommended by Mr. Stephenson and sanctioned and paid for by the Board of Directors.

'The peculiar nature,' says Mr. Fairbairn, 'of the investigation, and the almost total absence of data for the successful prosecution of the inquiry, operated in a great degree to retard its progress. The transverse strength of an iron tube composed of riveted plates *was an entirely new subject* (p. 209). . . . Weakness was found where strength was expected, and hence repeated changes of form as well as changes in the distribution of the material became absolutely necessary (p. 210). . . . We have not as yet arrived at the strongest form of tube; we are nevertheless *approaching that desideratum* (p. 15). . . . Some curious and interesting phenomena presented themselves in these experiments. Many of them are *anomalous* to our preconceived notions of the strength of materials, and *totally different* from every theory yet exhibited in any previous research (p. 39). . . . Although suspension chains may be useful in the construction in the first instance, they would nevertheless be highly improper to depend upon as the principal support of the bridge (p. 41). . . . The difficulties experienced in retaining the cylindrical tubes in shape, when submitted to severe strains, *naturally suggested the rectangular form*. Many new modes of this kind were prepared and experimented upon (p. 9). . . . *These experiments led to the trial of the rectangular form of tube* with a corrugated top, the superior strength of which decided me to adopt that cellular structure of the top of the tube *which ultimately merged* into a single row of rectangular cells.'—p. 12.

(Which Mr. Hodgkinson, as before stated, declares was the result of *his* previous calculations.)

Again, Mr. Fairbairn, on the 3rd of April, 1846, in reporting to Mr. Stephenson, states:—'It has already *been determined by experiment* that the strongest section yet obtained is that of the rectangular form;' and this being one of the important '*quæsita*' which Mr. Stephenson by the investigation he confided to Mr. Fairbairn and his colleagues had been desirous to obtain, it was by *his* recommendation approved of by the Board of Directors and finally adopted.

Having now concluded our extracts from Mr. Fairbairn's book, on the merits of which we have, for his sake, examined scarcely any other witness than himself, it only remains to be observed that annexed to the volume there are a series of costly plates curiously indicative of the text. Mr. Fairbairn states—

> 'It will, I think, be generally allowed that it was very natural I should desire to have my name *publicly* (Ital. *sic*) associated with Mr. Stephenson's as Joint Engineer for these Bridges.'—p. 170.

And accordingly in his plates Mr. Fairbairn has offered to the public a beautiful

PERSPECTIVE VIEW OF A PORTION OF THE BRITANNIA BRIDGE
'RESTING ON THE CENTRE OF THE MENAI STRAIT.
'ROBERT STEPHENSON AND WILLIAM FAIRBAIRN, ENGINEERS.'

Now the facts of the case, or rather of the picture, are briefly as follows :—

1. The masonry of the lofty tower, so faithfully represented, was erected under the *sole* superintendence of Mr. Frank Forster, C.E.

2. The tube, not so correctly represented,—inasmuch as, from the date of Mr. Fairbairn's retirement, nearly two years must elapse before it can attain the position it occupies in the picture,—has almost entirely been constructed under the sole superintendence of Mr. Edwin Clark, C.E.

3. Mr. Fairbairn did not for a single day work at the construction of the tower, or, excepting a few occasional visits, at that of the tube.

'SIC TRANSIT GLORIA MUNDI.'

CHAPTER VI.

MORAL.

THE sums expended by the Chester and Holyhead Railway Company to the 30th June last have been as follows:—

	£.	s.	d.
Cost of Tubular Bridge for crossing the Conway	110,000	0	0
Ditto ditto ditto Menai Straits	500,000	0	0
Remainder of the line, &c.	2,971,587	0	0
Total expenditure	3,581,587	0	0
Contribution to be paid towards the construction of the Holyhead Harbour of Refuge	200,000	0	0

Present market-value of original stock, 72 per cent. discount.

Ditto of preferential stock at 5½ per cent. interest issued by the Company to obtain funds to complete the works 20 per cent. discount.

The above figures strikingly illustrate the consequences of the system, or rather want of system, which the Imperial Parliament has hitherto pursued in railway legislation.

If the communication between England and Ireland *viâ* Holyhead, had—on the principle which at the time we earnestly recommended—been considered as one great arterial line, the proportionate expense of contributing to a harbour of refuge, as well as the enormous cost of raising the two bridges necessary for crossing the Conway and Menai Straits to a height sufficient for the distinctly different purposes of railway traffic and the sailing of large vessels, might, with some appearance of justice, have been thrown upon the aforesaid large Company;—although, in the day of M'Adam roads, Telford's bridges over the very same places, and the construction of harbours, were considered as *national* works, and were accordingly executed at the cost of the public. Very improvidently, however, the moderately remunerating portions of the line were *first* established by Parliament;—and thus the little Company which, with feeble means, was to continue from Chester the circulation of the Royal mails—of goods of all descriptions—of first, second, and third class passengers—and of Her Majesty's troops and artillery between London and Dublin, was saddled not only with its own natural burden, but with the preternatural works we have described; indeed, in order to obtain its Act of Parliament, it was so completely at the mercy of the Government, that it was obliged to submit to certain excruciating terms which—with the non-payment to the Company of its 30,000*l.* a-year for the mail-service, which the members of the late administration well know was ensured to it—and with a competition between the Government and the Company's steamers most lamentably inflicting a serious loss upon both parties—have, it appears, reduced the value of its shares in the market by more than 70 per cent., and, of course, completely drained its capital of all dividend. '*And,*' it has been said, '*so much the better for the public!*' Be it so! we have no desire to relieve the proprietors of the Chester and Holyhead Railway from the terms (whatever they may be) of their contract. On the other hand, there can be no doubt that, if Parliament holds every Railway

Company hard and fast to its bargain when it has made a bad one, it ought not, at all events, by *ex post facto* legislation, to let loose the public from every imprudent engagement which they, on their parts, have contracted to perform. We will exemplify our meaning by a particular case.

At the fag-end of last session Lord Monteagle introduced into the House of Lords a bill, which, though hastily approved by a vote of that House, was very properly, as we think, discountenanced by Lord John Russell, and finally thrown out in the House of Commons, to deprive railway proprietors of the power they now enjoy of solely auditing their own accounts.

It was not attempted to be shown that an auditor appointed by the public could increase the number of trains —improve station accommodation—or give additional security or even comfort to any description of persons travelling by rail. It was not attempted to be shown that the proposed measure would confer a single additional privilege upon railway *share-owners.* On the contrary, it was frankly admitted that '*to* THEM *the books of the Company are by law at all times open;*' but as a highly popular doctrine, it was honestly and unscrupulously explained that the real object of the proposed audit-bill was to enable *the public*, by legislative 'clairvoyance,' accurately to ascertain the present and prospective state of every Railway Company, in order that the proprietors thereof might be prevented from any longer selling their shares to the aforesaid 'public' at prices above their intrinsic value.

If Parliament were to force every horse-dealer to divulge the vices and infirmities of the sorry animal he is at this moment 'chaunting,' there can be no doubt that the public, by a general illumination, would have vast reason to rejoice. If Parliament were to oblige the proprietors of all quack medicines to pre-publish the exact cost of the ingredients which compose them, there can be no doubt that John Bull might henceforward repeatedly swallow a peck of pills for less money than he is now paying for 'a single ounce box.' In fact, for aught that we in our sequestered hermitage know, it may be very possible, that if every merchant's ledger were, to-morrow morning, by legislative enactment, to be declared public property, the prices of sugar, tea, iron, hides, coals, and a hundred other articles in the market, would, in the course of a few hours, be lowered. It has, however, hitherto been considered that the British merchant's counting-house is as much 'his castle' as his residence; that his accounts are as sacred as his person; and that, morally speaking, nothing but a suspension of the *Habeas Corpus* Act can authorise the seizure of either the one or the other.

When Mr. Stephenson's magnificent project of a cast-iron bridge of two arches, 100 feet high at the crown,—which, instead of costing 600,000*l.* (being at the rate of 1000*l.* per yard), could have been executed for 250,000*l.*,—was rejected by the Admiralty, that powerful Board very justifiably declined to advise by what other means the stipulations they required should, or even *could* be effected. The doubts, the difficulties, the risks, and the uncertainties were all, with an official shrug, very prudently thrown upon the little Company; and if the *expenses* of the Chester and Holyhead Railway could thus be legitimately forced into darkness, is it just, after the proprietors have not only performed their bargain, but have nearly been ruined by doing so, that their *accounts* should, by an *ex post facto* law, be dragged into daylight, not merely to gratify idle disinterested curiosity, but for the open avowed object of shielding the public—or rather public stockbrokers—from the very risk and pecuniary uncertainty which they (the proprietors) were forced to encounter?

But, as in all transactions 'honesty is the best policy,' so we submit that the proposed interference with the rights of Railway proprietors to be the sole auditors of their own accounts, is not only unjust, but impolitic. Thousands of owners of Railway stock have, by a fatal experience, lately learned that it is possible for a joint-stock company, as it is possible for any of the individuals composing it, to encourage profuse expenditure, to act dishonestly, and, for a short time, to veil impending ruin by mystified accounts. The antidote, however, to this poisonous admixture of indolence and fraud is already working its cure. The punishment of the principal transgressor has already become 'greater than he can bear;' and a salutary suspicion has not only spontaneously aroused the proprietors of two hundred millions of Railway property, who had hitherto very culpably neglected their own affairs, but has materially depreciated all Railway stock; and there can be no doubt that this wholesome castigatory depression of their property below its intrinsic value will, *to the evident benefit of the share-purchasing public*, continue to exist, until Railway proprietors have sense enough to perceive that it is their *interest* to remove the suspicion which created it, by the prompt establishment of that open examination, and that honest as well as disinterested audit of their accounts—(in the last half-yearly printed statement of the London and North-Western Railway Company's affairs we observe that there was expended in six months in 'audit and account 2488*l.* 5*s.* 6*d.*')—which will satisfy men of business; and which was, no doubt, Lord Monteagle's object, when—with rather more zeal than consideration—he proposed that it should forcibly be effected by Act of Parliament.

The desideratum, however, we feel confident, can be obtained by milder means ; and although between buyers and sellers of all descriptions contention must always exist to a certain degree, we trust that the proprietors of the rails which have gridironed the country, and those who travel on them, instead of unnecessarily snarling over the invention, will feel that it is alike their interest and their duty to join together hand in hand, magnanimously to develop to its utmost possible extent the greatest blessing, or at least one of the very greatest, which has ever been imparted to mankind.

It is generally asserted by railway proprietors, who are of course self-interested in the question, that the existing practice of rating their respective Companies according to their earnings,—their industry,—or, as it is technically termed, their 'profits in trade,' is unjust, because the same system, or fiscal screw, is not equally applied to landowners, manufacturers, or shopkeepers. It is argued that, so long as our old-fashioned highways, besides levying tolls, are allowed to tax for their maintenance every parish through which they pass, it is unreasonable that the same parishes should at the very same moment, by a process diametrically opposite, be allowed to transfer a large proportion of their domestic rates for the support of their poor, &c., upon railways, which, it is affirmed, have, generally speaking, not only grievously overpaid for the land they occupy, but have materially increased the value and prosperity of every city, town, village, hamlet, and field through which or near which they pass.

Upon this serious and important question, involving some general re-adjustment of assessments of every description, we shall abstain from offering any opinion, because we are convinced that sooner or later it will be duly considered by Parliament. In the mean while, however, it is with deep regret we observe that the innumerable direct as well as indirect impositions and taxes which—rightly or wrongly, legally or illegally—have been imposed upon our railways, are already producing the lamentable consequences we ventured to predict. From want of funds, even our greatest railway-companies are openly abandoning branch-lines which they had almost completed; they are reducing the number of their trains; economising at their stations; in fact, in various ways, in proportion not only to the expenses imposed upon them, but moreover to the reductions made in their original Parliamentary tolls, they are—perceptibly as well as imperceptibly—curtailing the convenience and accommodation which, from a sound regard for their mutual interests, they would most willingly have maintained for the public.

We feel confident that in this unfortunate, short-sighted, narrow-minded conflict the British Nation is discreditably warring against itself; and having not inattentively watched the practical working of the system, it has been our humble endeavour—by a few pen-and-ink sketches, which we now conclude—to attract the attention of the public to the magnitude of the works of our arterial railways, in order that, from the good sense and good feelings of the community, these new highways may receive that fostering protection and genial support without which the fruits of Science cannot be matured.

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